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The Institute is requesting from industry and persons interested in agriculture, financial assistance totalling £10,000 per year during each of the next three years. With this aid it is proposed to extend the Institute's activities to emphasise the importance of scientific agriculture to Australia and help in solving the problems of the financial stability of this country.

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Vol. 24 No. 1. March, 1958

Contents

REVIEWS—
Nematodes as plant parasites, by J. W. Meagher 3

ARTICLES—
The diversity of concepts about soils, by B. E. Butler 14
Potato breeding in New South Wales, by R. J. Jessup 21

TECHNICAL ARTICLES—
Ground spray treatments for control of banana beetle borer, by B. M. Braithwaite 27
Effective nodulation Vs. bag nitrogen in growth of subterranean clover, by Hilary F. Purchase 35
The induction of mutation in subterranean clover by X-irradiation, by J. A. Carpenter 39
Competition between wheat and three-cornered jack, by H. S. Hawkins and J. N. Black 45

TECHNICAL NOTES—
A salt meter for field use, by B. M. Tucker and M. Raupach 51
The colour of wool, by W. R. Lang 53
Staple length—quality number in Australian wool, by W. R. Lang, S. H. Moh and M. A. Muhmand 55
Weed control in pasture species trials, by A. J. Millington and G. A. Pearce 57

THESES 59

LETTERS 61

TALKS 63

NEWS ITEMS 69

INSTITUTE AFFAIRS—
Sub-committees in the Victorian Branch, by J. P. Brien 73
Personal Notes 76
Branch Notes 78

BOOK LIST 81

BOOK REVIEW 82

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Contributions are of three types, namely: "Articles", "Technical Papers" and "Technical Notes". For information about the size and form of each type of contribution, see page 2 of the March, 1955, issue of the Journal.

Manuscripts should be double spaced and should be submitted in duplicate, as part of the delay in referring is then avoided.

For more detailed information concerning the preparation and lay-out of scientific papers, authors are referred to the C.S.I.R.O. publication "Guide to Authors" and to an article entitled "The Preparation and Editing of Technical Papers" by N. S. Noble, published in the Australian Library Journal, April, 1954. The policy laid down in these publications is also largely followed by this Journal.

In addition to the contributions described above, the Journal is pleased to publish "Letters", "News Items", "Talks" and "Personal Notes" which have been received from, or which are of interest to, members of the Institute.

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Reviews

NEMATODES AS PLANT PARASITES

J. W. MEAGHER

Many plant diseases caused by nematodes have been recognized in this country for a long time. We are familiar with such terms as root-knot, bloat, or leaf eelworm, used to describe the plant symptoms caused by the attack of certain nematode species. In recent years, however, plant parasitic nematodes have achieved a much greater prominence in the literature of plant pathology because they have been shown to be of more significance to plant health than had hitherto been suspected.

This development has taken place mainly in the U.S.A., but important contributions to nematode research have come from many other overseas countries. Unfortunately, this field has been largely neglected in Australia where, except for a few plant pathologists who have from time to time studied the commonly recognized nematode diseases, there has been little nematode research conducted since the late Dr. N. A. Cobb left the N.S.W. Department of Agriculture early this century to join the U.S.D.A. Cobb was one of the pioneers of Nematology and, indeed, gave this study its name.

Following the increased attention being given elsewhere to nematodes and their relationship to plant disease, there has been renewed interest in nematology in this country and there are now several workers in this field. In general, however, agriculturalists are not familiar with the nature of parasitic nematodes and the ways in which they may cause plant disease. Some aspects of the diseases and damage known to be caused by nematodes both here and overseas are reviewed here.

Neglect of Nematodes

It may be asked why nematodes as plant parasites are now receiving increased attention? Why have their effects on plant growth been neglected?

There are several reasons for this, not the least important being the type of symptom usually caused by nematodes. Their effect is usually not spectacular in comparison with many diseases caused by fungi, bacteria or viruses. Nematode populations increase comparatively slowly and the result of their attack may be seen as a gradual decline in yield or as patches of poor growth appearing in a crop. Wilting in hot, dry weather may also occur as the result of damage to the roots or water conducting tissues of the plant. Such terms as soil sickness, soil tiredness, etc., have often been used to describe such symptoms and many theories, such as a mineral deficiency or an excess or lack of soil moisture, can be presented in attempting to account for such poor growth.

Some nematodes cause obvious plant symptoms, such as galling, and diagnosis of the disease presents no difficulty, but many species can easily be overlooked unless special techniques are employed to separate them from the soil or plant parts. Further, even if plant parasitic nematodes are known to be present, definite proof of their pathogenicity is often difficult to establish because, as they are

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obligate parasites, *in vitro* methods for their culture are not available. The position may be further complicated in many cases where nematodes are not the only pathogens concerned and, in addition to damaging the plant themselves, they may provide points of entry for fungal or bacterial pathogens.

The development which has most served to focus attention on the effects of nematodes on plant growth has been the production of effective soil fumigants. These have been able to demonstrate the often spectacular growth improvement following a reduction in population of parasitic nematodes.

What are Nematodes?

Nematodes are so called because they are unsegmented round worms belonging to the Class Nematoda. Many of them are widely known as worm parasites of man and domestic animals, but these constitute but a small number of the known species. They are world wide in distribution, occurring in both salt and fresh water and, in the soil, are often present in enormous numbers. Any handful of arable soil contains thousands of nematodes and Cobb (1915) estimated that 300 million nematodes lived in a single acre of soil, most of them in the top three inches.

Most of the species found in the soil are either saprophytic or predatory, living on micro-organisms and decaying organic matter or preying on their own kind and, therefore, may be classed as harmless or even beneficial. Some of them, however, are specialised for the parasitism of plants and are known to reduce crop yields.

Plant parasitic nematodes are minute slender worms which rarely exceed 1 mm. in length. They are often called eelworms because their general shape and manner of movement can be likened to that of an eel. This can only be observed when they are separated from the soil as, because of their small size and transparent bodies, they are invisible in the soil even though they may be present in large numbers. Despite their size, their bodies are a highly complex structure containing organs for digestion, excretion and reproduction, muscular and nervous systems, as well as specialised organs used to attack parts of living plants.

The mouthparts of parasitic nematodes are armed with a hollow protrusible stylet or spear which is inserted into the plant tissue and the cell contents are then sucked out. Some nematodes actually enter the tissues (endoparasites) while others feed by attaching themselves to the outside of the plant (ectoparasites). Not all plant nematodes are root parasites and some species attack the stem, leaves or flowers.

The diseases caused by plant nematodes can perhaps best be considered by grouping them according to the plant parts attacked and the type of symptoms produced.

A. Nematodes attacking stems (or stem structures) leaves and inflorescences. The symptoms they cause are more or less specific.

B. Nematodes attacking the roots. The symptoms they cause may be either specific or non-specific.

GROUP A

Stem Eelworms

The species *Ditylenchus dipsaci* is known as the stem and bulb eelworm and attacks a wide range of agricultural and horticultural crops. Stem eelworms live as obligate parasites in stems, leaves, flowers or bulbs and cause stunting, swelling or malformation. They breed continuously in the growing plant, but if their host is killed, they may enter the soil and invade fresh plants. If infested plant material is stored, the nematodes become dormant and, as they are resistant to desiccation, they are capable of surviving in this condition for a very long time.

D. dipsaci is best suited by a cool climate and in Europe the damage it causes is of particular importance. Crops attacked include oats, rye, mangolds, peas, beans, onions, lucerne, clovers, strawberries and various flower bulbs. Several distinct races or strains of the nematode have been recognized, each strain having its own host range.

In Australia it has been known for many years as a major cause of disease in narcissus, the symptoms of which are a rotting of the bulb and distortion of the leaves and flowers. Another strain attacks lucerne and clover and,

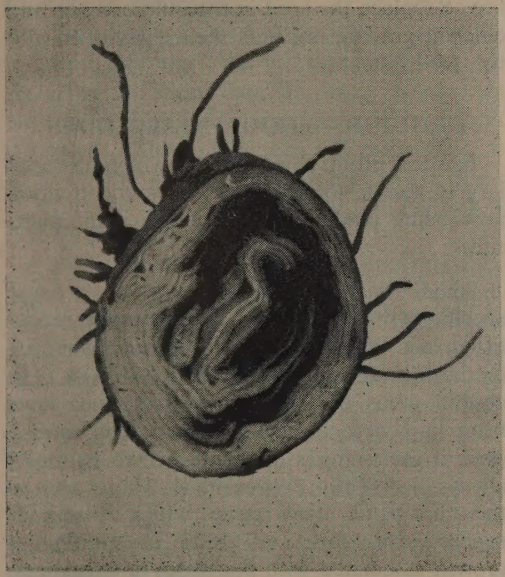

Figure 1—Stem eelworm (Ditylenchus dipsaci) on narcissus causing discolouration and rotting of the bulb.

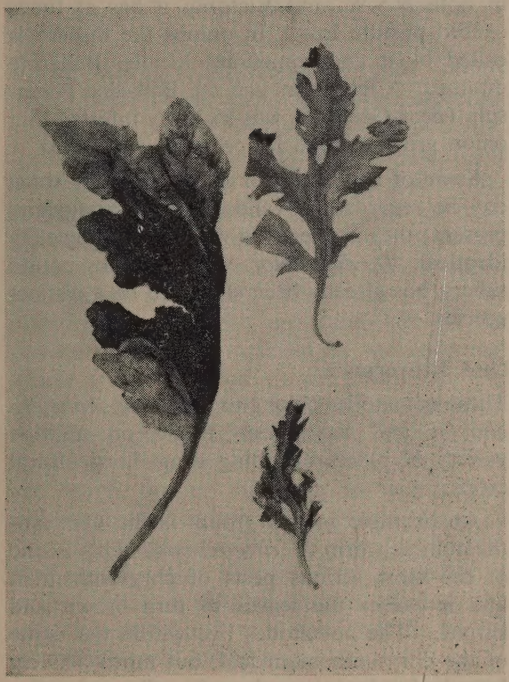

Figure 2—Chrysanthemum leaves infested with the leaf eelworm (Aphelenchoides ritzema-bosi).

Figure 3—Root-knot nematodes (Meloidogyne sp.) on Tomato.

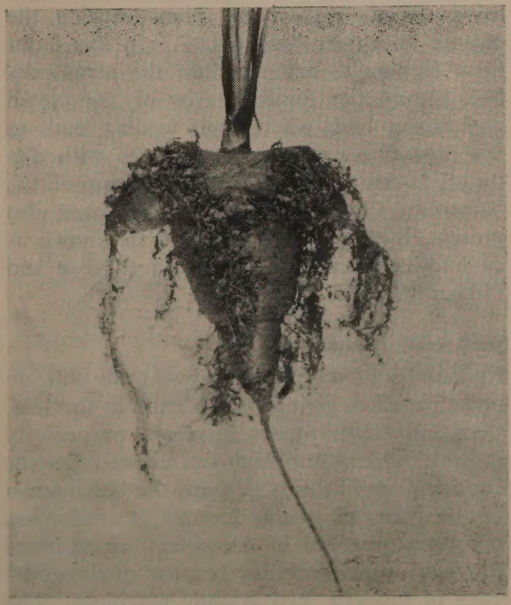

Figure 4—Root-knot nematodes (Meloidogyne sp.) on Carrot.

in both N.S.W. and Victoria, it has at times caused pasture loss. In onions the disease is called bloat and sometimes locally, Bellarine disease. A few years ago the Bellarine Peninsula (near Geelong) was so badly infested that onion growing virtually ceased in that area.

Some of the strains of *D. dipsaci* may some day be regarded as valid species, although at present they appear to be morphologically identical. *D. destructor,* which attacks potato tubers, has already been shown to be a distinct species.

Leaf Eelworms

These nematodes belong to the genus *Aphelenchoides* and have been found on a wide variety of plants including some horticultural crops.

An example in this group, is the Chrysanthemum eelworm *A. ritzema-bosi.* This is one of the most serious pests of chrysanthemum and it causes the leaves to turn brown and shrivel. The nematodes live within the tissue of the chrysanthemum leaf, but move actively from leaf to leaf through surface films of water.

A. ritzema-bosi and a closely related species, *A. fragariae,* may also damage the crown and leaves of the strawberry plant causing the disease known as "red plant". In this latter case, feeding as ectoparasites, the nematodes live among the folded leaves of the crown and runner buds where their feeding leads to the production of abnormal leaves with distorted leaflets. Where certain strains of the bacterium *Corynebacterium fascians* are also present, the more severe symptoms known as cauliflower disease are produced (Crosse and Pitcher 1952).

Seed Gall Nematodes

Nematodes of the genus *Anguina* are obligate plant parasites giving rise to galls in the leaf, stem and flower tissues of plants, particularly grasses. *A. tritici,* which causes seed galls or "cockles" in wheat, is perhaps the best known of the parasites in this group. *A. tritici* has not been observed in Australian wheat crops for many years probably because of the efficiency of modern seed grading machines. The hard round galls containing the nematode larvae replace the seed in the inflorescence and efficient grading prevents their carry-over with the seed wheat.

GROUP B.— ROOT NEMATODES

It is this group of nematodes which has been largely responsible for the increased attention now being paid to nematodes as plant parasites.

Some root-attacking nematodes cause specific symptoms which can be easily recognized, e.g. galling of roots (*Meloidogyne sp.*) or the formation of cysts (*Heterodera sp.*) In certain areas of Australia such species have been known to be present for a long time—even if their effects on plant growth have not always been fully appreciated. There are, on the other hand, many species which cause non-specific symptoms, i.e., failure or stunting of growth associated with poor root development, browning or decay, so that diagnosis is difficult without microscopic examination of the roots or soil population. It is the presence of these nematodes and their effect on plant growth which have, in general, been overlooked.

In feeding, the nematodes may damage the plant partly by a removal of cell contents, but also by the secondary effects this feeding may have on the normal functioning of the plant root. The digestive juices injected by some species cause giant cells or galls to form in the root which interfere with the translocation of water and plant nutrients. Some species may also retard normal cell differentiation or cause necrosis.

If cells are killed by the feeding or passage of the nematode, this tissue may be invaded by bacterial and fungal organisms which initiate a secondary infection. Indeed, in recent years this association of nematodes and other root pathogens is being demonstrated in an increasing number of diseases.

Feeding habits vary according to the species which may be ectoparasitic, endoparasitic, sedentary or migratory, and their host range may vary from one to several hundred plant species.

Root-Knot Nematodes

The root-knot nematodes (*Meloidogyne spp.*) are probably the best known and easiest to recognize of the root-attacking nematodes and have long been regarded as important parasites. They cause characteristic galls to form on the root ranging in appearance from a string of beads on smaller laterals to a heavily knotted root mass.

Larvae enter the root and the enzymes they inject cause giant cells to form, on the contents of which the nematode feeds. The female becomes sedentary and the development of eggs inside the body causes it to swell and become pear-shaped or almost spherical. Several hundred eggs are deposited in a gelatinous sac to form an egg mass. These may remain within the root or be deposited at the surface where they may hatch almost immediately or remain dormant until the next crop is planted.

Formerly, all root-knot nematodes were regarded as belonging to the one species *Heterodera marioni,* although strain differences had been observed in host resistances to nematodes obtained from different areas. In 1949 Chitwood demonstrated that morphologic differences existed between the strains. He identified several species and placed them in the genus *Meloidogyne.*

The root-knot nematodes are known to attack over 1700 species of plants and are most damaging in a warm climate. This does not exclude Southern Australia, where hundreds of acres of vegetable land, orchards and vineyards are infested with the pest. It is natural, however, that many parts of Queensland should be seriously affected, for a long growing season and high temperatures favour the activity of this parasite.

Cyst-forming Nematodes

Species of the genus *Heterodera* are known as cyst-forming nematodes and here again there have been fairly recent changes in classification. Formerly all cyst-forming nematodes were considered to be the single species *Heterodera schachtii,* although strain differences based on host ranges were recognized. In 1951 Franklin listed eleven species and varieties, and others have since been described.

The life cycle of *Heterodera spp.* differs from *Meloidogyne spp.* in some important aspects, as do the symptoms they produce. Although the invading larvae cause giant cells to form, there is not the marked gall formation which accompanies the invasion of root-knot larvae. An excessive number of lateral roots, sometimes known as starvation rootlets, are usually produced. The fertilised female becomes swollen with eggs and lies on the surface of the root attached by the head end which is still inserted in the root. At this stage, their white lemon-shaped or spherical bodies are easily visible to the naked eye. The body wall of the female then becomes thickened and tough, turning brown as the worm dies, and is transformed into a cyst. Several hundred eggs are contained in this cyst and these may remain viable in the soil for a number of years. When a suitable host is planted, the eggs are stimulated to hatch and the larvae invade the roots of the host.

Only two species of cyst-forming nematodes have so far been recorded in Australia. Of these, the cereal eelworm *H. major* is by far the more important. This species occurs commonly in the wheat growing areas of the Wimmera and Mallee in Victoria, and areas of South Australia. Although its effect is most spectacular in certain seasons, particularly when the winter is very wet, each year there is a considerable reduction in the yield of wheat and oats grown on infested areas.

H. schachtii (sensu stricto) the beet eelworm, affects red beet and cruciferous crops in a few market gardens near Melbourne and Adelaide, but in these places it is usually possible to practise a sufficiently wide rotation to avoid serious losses.

We are fortunate that other species of *Heterodera* have not been found present in Australia, as many of them are important parasites. The best known of these is the potato root eelworm (Europe) or Golden Nematode (U.S.), *H. rostochiensis.* This eelworm is a major problem of potato production in Europe and is estimated to cause an annual

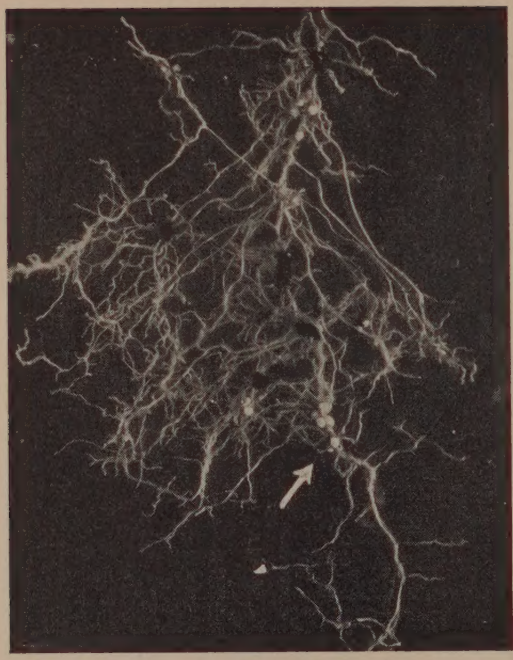

Figure 5—Oat roots infested with the cereal eelworm (Heterodera major) showing white cysts on the roots (arrow).

Figure 6—Effect of fumigation of soil infested with beet eelworm (Heterodera schachtii). Beet from fumigated soil left and from unfumigated soil right.

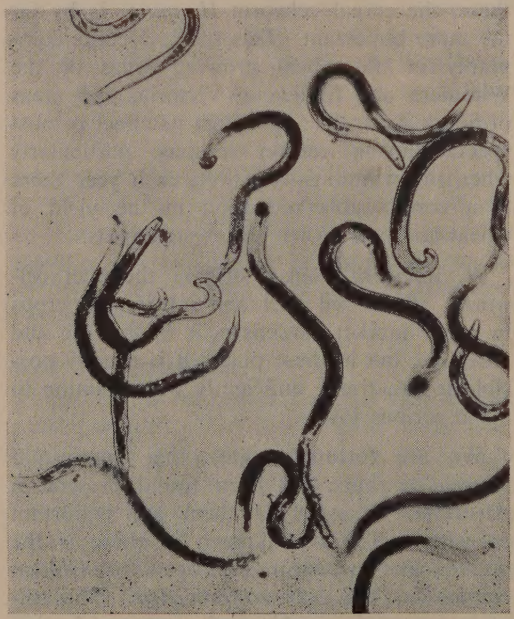

Figure 7—Root-lesion nematodes (Pratylenchus sp.) separated from soil (x 130).

Figure 8—Damage to apple roots caused by Pratylenchus sp. Note the absence of fibrous roots.

loss of £2,000,000 in the U.K. alone. Quarantine authorities in all parts of the world where potatoes are a major crop, and particularly where *H. rostochiensis* does not occur, are aware of the importance of preventing the importation of infested plant material, soil or even ballast, in which cysts are likely to be contained. When the Golden Nematode was discovered on Long Is., U.S.A. in 1941, a special laboratory was set up on the island to study the nematode and attempt to limit its spread in the U.S.

In countries where this nematode does occur, apart from the great losses caused by the lowered yields on potato sick soil, considerable expense is sometimes involved in the inspection of potato fields to ensure that seed potatoes are not grown on infested land.

Citrus Nematode

Another nematode which causes more or less specific symptoms is the citrus nematode *Tylenchulus semipenetrans*. Roots infested with this nematode can be distinguished by the soil which adheres closely around the root, held there by a sticky exudate surrounding the nematode eggs. Only the outer layers of the root are penetrated and the female becomes sedentary and swollen in appearance before egg-laying commences.

This nematode is widespread on most of the citrus growing areas in Australia but, although it may often be found in very high numbers on citrus roots, its effect on adult trees is usually not obvious. However, in the U.S. its effect on the vigour of young trees has been shown to be very important and may reduce growth by 40-60 per cent. (Baines and Martin 1957).

Once thought to be confined to *Citrus spp.* it has been found to occur commonly on vines in the Murray Valley irrigation area (Seinhorst and Sauer 1956). Its effect on the growth of the vines is not yet clear.

Root-lesion Nematodes

The occurrence of root-lesion or meadow nematodes, *Pratylenchus spp.*, appears to be widespread on a large number of economically important crops and the importance of this genus has certainly been underestimated in the past. This is because they cause more or less non-specific symptoms and often the primary cause of disease has been ascribed to root rots which may follow their invasion. Steiner (1945) considers root-lesion nematodes to be "one of the most important primary factors in root destruction among cultivated and uncultivated plants".

These nematodes are endoparasites of the fibrous root system causing lesions, root browning or necrosis. Although the plant may put out new roots, under conditions of high infestation, they may be almost completely destroyed. The nematodes do not become sedentary, but may move from root to root laying eggs in the soil or in the root itself.

The taxonomy of this genus was confused until Sher and Allen (1953) recognized ten distinct species. Others have since been described, but the host range of each species is as yet far from clear. As a whole, the genus attacks a very wide range of plants and several species have already been found to be associated with many cases of poor growth and replant problems in Australia.

Elsewhere, they have been found to be very important in their relationship to replant problems of fruit trees and other perennials. Colbran (1953) showed *P. coffeae* to be the cause of poor growth of replant apple trees and the decline of adult trees at Stanthorpe (Q). *P. penetrans* and *P. pratensis* have been found associated with many similar problems of apple trees in Southern Australia.

P. vulnus and *P. scribneri* are commonly associated with poor growth of vines, while *P. penetrans* has often been found to be present where the growth of strawberries and some vegetable crops have failed. Root-lesion nematodes are well known as the cause of failure in these crops overseas.

Burrowing Nematode

The burrowing nematode, *Radopholus similis*, is, like the root-lesion nematodes, a migratory endoparasite and, as its name implies, feeds on the cortex tissues of rootlets forming burrows and cavities.

It has been commonly found in banana roots in Queensland (Colbran 1955) and, although mainly confined to tropical plants, mention must be made of it here as the cause of a destructive disease of citrus known in Florida (U.S.) as Spreading Decline. First shown to be the cause of the decline by Suit and Ducharme in 1953, it has come to be regarded as the most important trouble effecting citrus groves in Florida and attempts to control or eradicate it have been very expensive.

A banana attacking strain of *R. similis* (Ducharme and Birchfield 1956) does not attack citrus and, as *R. similis* has never been recorded on citrus in Australia, it is probable that the citrus attacking strain does not occur here.

Ectoparasitic Nematodes

Before the widespread use of soil fumigation in the United States, nematodes living ectoparasitically on plant roots were almost completely neglected as the cause of crop failure. These nematodes feed by inserting their stylets in the outside of the roots and are usually removed when the plant is disturbed. They must, therefore, be looked for in the soil. Like the migratory endoparasites, they retain their eel-like shape throughout their life cycle.

The sometimes unexpected responses to the application of soil fumigants focussed attention on nematodes which feed in this way and a number of genera are now known to have important effects on plant growth. Most of them have been given common names often relating to the stylet used to puncture the plant roots. They include lance nematodes—*Hoplolaimus sp.,* dagger nematodes—*Xiphinema sp.,* stylet nematodes—*Tylenchorhynchus sp.,* sting nematodes—*Belonolaimus sp.,* stubby-root nematodes—*Trichodorus sp.,* pin nematodes—*Paratylenchus sp.,* awl nematodes —*Dolichodorus sp.,* ring nematodes—*Criconema sp.* and *Criconemoides sp.* and the spiral nematodes—*Rotylenchus sp.* and *Helicotylenchus sp.* among others.

The poor growth or patchiness of the above ground parts of an affected crop is similar to the general symptoms of eelworm attack. Although they may not be diagnostic, the root symptoms vary according to the nematode species and crop attacked. These symptoms range from a stunting of root growth resulting from root tip injury, sometimes with proliferation of short roots above the point of nematode attack, to browning, necrosis, or general root decay.

Although species of all the above-listed genera have already been detected in Australian soils, some of them associated with crop plants, their effects on growth have not yet been clearly demonstrated. Elsewhere they are known to seriously affect such crops as cereals, tobacco, cotton, maize, peanuts, lucerne, turf, nursery stocks, ornamentals and many vegetables.

Nematodes and Disease Complexes

In the United States in recent years breeding for resistance to certain wilt diseases has been made more complex by the finding that nematode infestation can break down the wilt resistance bred into some crop plants. Resistant plants can become susceptible to the disease where nematode damage allows the fungal or bacterial pathogen to enter. Furthermore, susceptible plants may be affected to a greater degree where certain parasitic nematodes are also present.

In resistant plants they have been found to increase the expression of Fusarium wilt of cotton, black shank and Granville wilt of tobacco, Fusarium wilt of tomato and bacterial wilt of carnations. They have been shown to increase the severity of Fusarium wilt of tobacco and Rhizoctonia of cotton as well as being recognized as the primary agents in complex root rots of many other plants.

The list of cases in which nematodes have been demonstrated to be members of such soil-borne disease complexes continues to grow and, as evidence accumulates, it may prove to be their most important role in plant disease.

Effect of Crop Rotation

The degree to which a host plant will be damaged by nematode attack is related to the population level of the nematode species and its rate of build-up.

Rotation of crops, to include non-susceptible or resistant crops, to prevent the build up of a particular species is therefore important. Where some of the better known nematode diseases have occurred, it has long been realised that where the rotation is too narrow crop yields can be greatly reduced, and repeated cropping with a susceptible crop eventually results in crop failure. Wheat crops in areas of the Wimmera infested with the cereal eelworm, *H. major,* are always more severely affected under the two course rotation of wheat—fallow. In Germany, during the last century, too frequent cropping of sugar beet on land infested with *H. schachtii* almost resulted in a complete breakdown of the sugar beet industry.

It is now being realised that the effects of some of the less obvious plant nematodes may have been more insidious. According to Taylor (1953) ". . . . all of the crop and ornamental plants in the world can be attacked by parasitic nematodes. If there are exceptions to this rule, they must be very few indeed".

All plant nematodes are more or less specialised in the plants they will attack, but because of their widespread distribution, they must often play an important role in the benefit known to result from the practise of wide rotations. Oostenbrink, S'Jacob and Kuiper (1956) have presented evidence which suggests that the success of some long established systems of rotation may be based, at least partly, on their dynamic effects on populations of the nematode complex in the soil.

Methods of Spread

It might be expected that Australia, being so long separated from other continents, may have a unique nematode fauna. Although it is certain that many new species are to be found here, our important plant parasites appear to be identical, or very closely related, to those found elsewhere. Indeed, the world wide distribution of plant nematodes indicates that man has been chiefly responsible for their spread, not only by transporting them over long distances either in soil or attached to plants, but by distributing them over an infested field through cultivation, or the movement of vehicles, men and farm animals.

Movement by water, and sometimes even wind, may also play a large part for, unaided, nematodes move only short distances through the soil; usually only a few feet in a year. As their rate of build up is slow, it may be some time after their arrival on a new area before their effects are observed, and by this time they may be well distributed.

Methods of Control

Where the yield of high value crops are seriously reduced through nematode attack, soil fumigation with materials such as D.D. (a mixture of dichloropropane and dichloropropene) or E.D.B.(ethylene dibromide) is sometimes practised. This is an expensive process, and although yield increases of 25 per cent. to 50 per cent. after soil fumigation are common, it can only be a temporary expedient, as the nematodes are not eliminated from the soil. Soil fumigation can only reduce their numbers in the soil to enable a young crop to become well established. As the crop grows, their population will increase, but too late to greatly affect the plants. Fumigation must be repeated at intervals, since the nematode population soon increases to the level where it once more appreciably affects the yield. Since the fumigants mentioned above are phytotoxic, their use can only be applied to annual crops, but development of newer nematicides may allow perennial crops to be treated.

Other methods of reducing the soil population have also been practised. As most nematodes are susceptible to heating and desiccation, fires are sometimes lit over seed bed areas and land is sometimes thoroughly cultivated during dry summer months. To control cyst forming nematodes the use of trap crops has been suggested and two systems are possible. The first, is to grow a susceptible crop which will stimulate the eggs to hatch and larvae to invade the roots, but to destroy the crop before the completion of their life cycle. As this method would have to be well timed to succeed, it has not been generally practised. The other possibility is to grow a crop to which larvae are attracted to enter the roots,

but in which they are not able to complete their development. Finding suitable plants is the greatest difficulty in this case.

The most satisfactory method of control is the use of crop rotation and nematode resistant plants. This requires a knowledge of the host range of the nematode and a programme of plant breeding for resistance. Some crop plants resistant to certain species of nematodes have already been developed, but a great deal has yet to be done in finding sources of resistant material and its incorporation into suitable varieties.

Present and Future Importance

As we do not yet have an adequate understanding in this country of the extent of damage caused by plant parasitic nematodes, it is not possible to give an estimate of the losses they may cause. However, as many important parasites have already been found to be widely distributed here, we can be sure that it is considerable and, on a smaller scale, can be compared to losses experienced overseas. Taylor (1953) says: "I have no reliable estimates of the amount of damage nematodes do to crops in the United States each year, but there is general agreement that it is at least several hundred million dollars".

Agricultural scientists not directly concerned with plant diseases may, in the future, become more aware of nematodes as a factor in plant growth and Thorne (1957) says: "Nematologists have long been aware of the fact that plant parasitic nematodes may be a serious disturbing factor in field, plot and greenhouse experiments. Unfortunately, other workers in plant breeding, soils, fungicides, insecticides and fertilizer testing are unaware of this fact, and frequently their results are completely upset and confused by nematodes".

By comparison with insect pests and diseases caused by fungi, bacteria and viruses, we have heard little of the damage caused by nematodes, but it is certain that much more will be heard of them in the future.

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Articles

THE DIVERSITY OF CONCEPTS ABOUT SOILS

B. E. BUTLER

For some time past the writer has been impressed with an appearance of uncertainty in the objective of much published soil work. This consideration applies mainly to soil surveys and pedological studies, though it applies to some studies of an agronomic and soil-chemistry nature too. It is possible to discern several objectives in these studies, and each of these objectives implies its own concept of soils. In this paper it is proposed to state three of these concepts, to enlarge upon the logical steps entailed in each one, and to determine how far these steps have been followed in past work.

The three concepts discussed here will be shown to be quite diverse in their nature. But because this diversity has not been uniformly recognised by all soil workers, confusion in the use of words may result unless the reader notes their definition here.

Three of the concepts which may be discovered in the soil literature referred to, may be named the edaphic, the pedologic and the geographic, and these will be discussed here. It is realized that these headings are not entirely comprehensive, but they nevertheless cover the greater part of the field of interest. One other heading which will only be mentioned here is that which treats soil merely as a material having properties which may be put to use in structural, manufacturing or engineering undertakings. By the edaphic concept is meant those ideas concerning the plant growth factor of soils. By the pedologic concept is meant those ideas regarding the development of soil profiles and soil materials, and in the geographic concept is included those considerations of soil as it occurs in the landscapes of the world.

That these concepts concerning soils are current is indicated by the following extracts from the "Soil Survey Manual", (Soil Survey Staff, 1951, pp. 6, 7 and 8.) These extracts are taken from the section discussing the definition of soils; they are not presented here in the order of their occurrence in the reference.

The edaphic concept—"First of all, soil is the natural medium for the growth of plants."

The pedologic concept—"We think of soils as including the upper part of the earth's crust that has properties different from rock material because of the influence of the soil forming factors".

The geographic concept—"A soil is a dynamic three dimensional piece of landscape. . . . Soils then are landscapes as well as profiles."

Soils Considered from the Edaphic Viewpoint

The field of interest here is restricted to those soil conditions which are of significance to the growth and life-economy of plants. The problem is to assess the plant growth potential of soils, and to determine means to correct any deficiency in this regard. It is interesting to recall that, in the earlier days, it was proposed (Shaw 1930) that the term edaphology should be used for the science, which is now generally called pedology. This proposal indicates the large share that edaphic interest had, and indeed

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continues to have, for a great many of the people concerned with the study of soils.

The edaphic concept would logically entail development of the following points:—

1. The specific needs of plants in terms of rooting space and its conditions of humidity, aeration, tilth and temperature: and their needs in terms of nutrients. The needs of different plants vary so widely that conditions which suit one species may be quite prohibitive for another.

2. The significance of soil properties in meeting the needs of plants. This means the determination, in appropriate terms of the soil's aeration, moisture regime, temperature and supply of available nutrients.

3. The seasonal environment provided by the soil in terms of changes in temperature, moisture, and the biological fluctuations in competition, synthesis and decay. The meteorological conditions *per se* cannot come under the headings of edaphic, though they are clearly definitive for plant growth.

4. Methods and techniques for determining: (a) the specific needs of plants, and (b) the deficiencies of soils, and (c) for measuring responses to ameliorants.

The practical value of this edaphic theme has resulted in a great amount of attention being devoted to it. However, if the above mentioned points are a logical statement of the theme, it has not been developed very far. The first objective, the determination of the needs of plants, has very rarely been made in the specific terms which a scientific discipline requires. Indeed methods for obtaining these data (point 4a) have not gained any general currency.

Much of the work in the edaphic concept, has been done by agronomists, without any other than an edaphic interest. But a great amount has also been done by soil workers, particularly soil surveyors, whose work is influenced not only by the edaphic but also by both the pedologic and the geographic concepts—as defined below. In most cases, the agronomists have looked to the soil worker to provide the rationale on the soil side.

Most of the soil surveys done in recent years have been at the request of those interested in agronomic problems; however, the soil surveyors, because of their concurrent attention to the geographic and to the pedologic theme, have not given a simple statement in agronomic terms. Their work has resulted in the creation and delineation of a number of soil types, and these have been presented in the form of a profile of stated texture, structure, colour, thickness, reaction, etc. The transposition of these characteristics into terms of specific edaphic significance (point 2) is very rarely made. The soil surveyors have usually fulfilled their edaphic obligations by simple analogy; i.e. an observed crop response on one area of type "x" is presumed to be a potential of every other area of type "x". The validity of this assumption is conditioned by the fact that soil type criteria are not solely or even mainly edaphic in nature. But even with this reservation, the edaphic assessments facilitated by soil surveys are restricted to crops that have already been grown in the area. Without obtaining data under the points enumerated above, no further edaphic assessments are possible, except at the level of personal judgements. These may of course be quite expert and based on long experience, but they have no scientific backing.

On the regional basis, soil survey work has resulted in a tremendous proliferation of soil types. The edaphic significance of many of these remains unproved for many years. The categorization of soil types, in terms of their edaphic significance, has been attempted at some centres and examples may be quoted such as the Storie index (Storie 1933), the Soil Conservation Classes (anon 1954), the Bureau of Reclamation Classes (anon 1946), and the Saskatchewan rating system (Mitchell 1940). All of these categorizations effect a great amalgamation of the soil surveyors' units. This is to be expected since a great many of the distinctions between soil types are of a pedologic and geographic nature, as well as those which have edaphic significance. Conversely, however, edaphic relevance may require the splitting of some soil types.

The workers in the purely edaphic field, the agronomist or horticulturist have usually accepted the soil surveyors' categories or where these are patently unsuitable, they have devised their own. There clearly seems to be

a need for a philosophy and a method based wholly upon the edaphic concept, and this will require the work of both the agronomist and the soil worker. The existing accumulation of data in this field should be correlated and systematized to give a method by which the problems of the future may be more efficiently handled than they have been in the past.

But it must be conceded that the edaphic approach is not easy. There is reason to suppose that any attempt to evaluate the edaphic factor must be limited to a set environment. The plant growth potential of a site or area resides in its climatic and environmental factors, as well as in its soil factors, and these may be equally decisive in the outcome. At certain levels, they may change the relevance of the soil values. It is plausible therefore, that the edaphic theme should be viewed in the wider framework of the ecosystem (Tansley 1935).

The assessment of plant growth potentials and the edaphic factor, clearly needs much further consideration if they are to be welded into one coherent system.

The Pedologic Concept

The term pedology is used here to cover the study of soils as an independent discipline: the objective study of soils and soil materials, the principles of their occurrence and the processes of their origin. To be objective, the rationale for the study must be sought in the nature of the material itself. A soil has developed from something which was not soil and hence the notion of development is a key one. Soil development is the unique organization involving vertical differentation which occurs at an exposed ground surface. It is proposed that this is influenced by the environmental conditions of the site, and that time is a factor in it. The problem is to understand the processes by which soil characteristics develop, the conditions which govern these processes, and the principles of soil occurrence.

The pedologic concept would logically entail development of the following points:—

1. Determination of the factors governing the formation and persistence of separate ground surfaces, since it is on these that soil systems develop. Applied to a particular locality, this would lead to the recognition and delineation of the array of ground surfaces occurring there, their mode of origin, and the surface history of the area.

2. For particular localities to determine the range of soils occurring on each ground surface, and to consider the development of these in relation to the prior state of each.

3. By the study of selected soils, (selected because their prior state, age and history, are most clearly known, and because they are single, uncomplicated systems), in comparison with their former state, to formulate proposals as to the nature of the soil forming processes and to test these in prepared laboratory models, so that both the processes and the conditions governing them may be studied.

4. To study the commonly occurring soils in given localities in the light of the foregoing. These may be either single or multiple soils, or they may refer to one soil system or several. This study would comprise the principles of soil occurrence in the area.

5. The application of the foregoing data to the understanding and use of specific soils and localities.

In nearly all published reports soil studies in the pedologic theme have not proceeded along the above lines. Generally there has been no clear recognition of the prior state of the soil material, duration of its exposure as a surface, nor of the history of events and conditions it has been exposed to. Studies which have aspired to pedologic conclusions have usually assumed that the substratum was the parent material of the soil profile, and that soil development, the present climate, and the vegetation, were all coeval. There has been a general absence of proof, largely because the necessary information, and in some cases the method for deriving such information, was not available.

Many of the pedologic studies reported in the literature have been made on soil profiles selected because they were representative of certain geographic types (discussed below). Whether or not these profiles could conform to the requirements of selection proposed in point 3 above, cannot be anticipated. From the purpose and objectives of the geographic

concept, there is no reason why its type profiles should comply with these requirements. Pedologic studies based on geographic types, must therefore be of doubtful value.

Notwithstanding these difficulties, a considerable amount of soil studies proceed to the next stage (the second part of point 3 above), that of formulating proposals about soil forming processes. Thus the processes of podzolization, solidization, gleying, laterization, degradation and others have been freely used in the literature for many years. In addition to the uncertainty of the premises on which these processes are formulated they have not, with few exceptions, been carried to the stage of verification under controlled conditions.

In some cases specific soil profile arrangements have been taken as indicating a certain soil process, and profiles have been chosen for pedologic study because they most ideally present these profile arrangements. This line of reasoning does not obviate the need to establish proof of the prior nature of the profile, its degree of vertical uniformity, and indeed its unity, as one soil profile, rather than a super-position of two or more.

Though existing pedological data must be tentative to a high degree, much of it has been incorporated in soil survey work, and other soil studies. Thus, some soil types are distinguished from others because they are solodized or gleyed, and also studies have been made on the relationship between such soils and land use factors, and again between such soils and geographic factors. Because of the admitted uncertainty of the processes entailed, some workers choose to restrict terms such as solodized and degraded, etc., to the assemblage of profile features, and not to the process; but it is doubtful if the genetic connotation can be evaded by these means.

Though there is a general absence of proof in the pedologic field at the present time, the mass of experiences suggests that soils differ from their parent materials in the segregation and specific organization of sesquioxides, clay, lime, organic matter and salts in a soil profile, and in certain structural, consistence and colour arrangements. Further development of sound data in the pedologic theme is probably held up chiefly by the paucity of data and means of proof concerning the prior state, the age, and the history of existing soils.

By a comparison of their several themes and objectives, it is clear that the pedologic concept is quite distinct from the edaphic concept. Their development and methods of working, even their significant analysis, are quite distinct. Their common points are certain, as yet unspecified, soil properties which have edaphic implications. Pedological studies will indicate the full nature of such properties, their mode of development, and hence their mutability. Pedologic studies will also provide an understanding of the distribution of soils, and hence of certain edaphic implications.

The Geographic Concept—Soils Considered as Landscapes

This theme refers to the study of areas of land; it recognises the repeated occurrence of natural areas of relative uniformity in terms of soil, lithology, topography, vegetation and local climate. Its objective is the recognition of these, the compilation of maps showing their occurrence, and the understanding of their meaning and use. The term geographic is appropriate for this work, because it is largely one of integrating all of the factors that bear upon the comprehension and use of sections of the countryside.

The geographic concept would logically entail development of the following points:—

1. The recognition of areal entities, representing generalized uniformity in soils, topography, lithology, plant communities, and local climate conditions. Entities of this sort may be established at several levels of generalization, extending from the level of great soil groups to the level of soil types. In this paper, these entities, for the sake of convenience, will be called geographic types, and the component aspects—the soils, topography, lithology, local climate and vegetation —the geographic associates.

2. The delineation of these areal entities on maps. Associated under this heading are the various means that must be adopted for simplifying the complex patterns of actual occurrence, so as to suit the various stages of generalization for which the work may be required.

3. The study and rationalization of the geographic types, particularly with regard to the inter-dependence of the geographic associates.

4. The appraisal of the geographic types for use.

The geographic types are created as a more or less complete integration of the geographic associates, and the task of integration may be considered as coming within the province of the Geographer; however, at the detailed level at least, both soil and ecology workers have been more active in this field. The Geographer would be concerned with the impartial integration of the component aspects of a region, its geology, geomorphology, pedology, ecology, and climate. The Ecologist is concerned with the habitats occurring in a region, and considers the soils, climate, topography, lithology and vegetation as they bear upon this.

Of the components of the geographic complex, the soil worker give particular emphasis to soils, and this could be justified on the basis that the soil, having developed under the site conditions provided by the climate, topography, vegetation, and lithology, would bear a direct response-relationship to these. This proposition would be valid in those cases where the soil, and its geographic associates were coeval, and this has been assumed in much of the earlier soil work. Though this may be true in certain instances, adequate principles for testing the situation, have yet to be developed.

It is clear that where the soil had developed under site conditions other than those now prevailing—and this could be due to changes of climate and or vegetation—this unique significance of the soil will not obtain. Evidence is accumulating that many soils may have persisted through several climatic phases, and hence through several assemblages of geographic associates. In consequence, soils can no longer be assumed to have the dominant role among the geographic associates, and their integration must be upon some other basis. This may be derived to some extent from the Geographer's integration of the associates, from the Ecologist's assessments on habitats, or from the soil workers' estimation of edaphic or pedological relevance.

This statement of the motives and criteria of the soil mapper is of necessity involved and uncertain because of the lack of any one unchallengeable basis for his work. The soil profile which he is to map extends as a continuous range of variation, and he must divide this into segments, which have as much reality as possible, and which are mapable.

The choice of the boundary point is the crux of the problem. The soils themselves elect no one point before another, so that the soil worker must choose on some other basis. He may do this at the point of a proved or presumed critical value of habitat, edaphic value, or soil process. In addition, or as an alternative when these are unknown, he chooses a point which is mapable. This may be a point of topographic, vegetation, or lithologic change, or more preferably, where changes in several of these coincide with one another, and with a rapid change of soil. The boundary point may be chosen by any of these means, and the more that several of them coincide, the better justified the choice seems to be.

The amount of soil variation included in a soil type thus becomes that amount which occurs between one such boundary and another. All of these considerations are to be evaluated according to their occurrence over an extensive district; if they recur many times over, they have greater significance than if they were to occur once only. Indeed, in the latter case, the data would have no value to the geographic theme, whatever its other significance may be.

It happens by these means that the soil surveyor's types come to have an appreciable, though variable, component of non-soil criteria and data. This occurs at the soil type level, and also at the great soil group level, as is evidenced by such names as alpine humus soil, desert loam, and stony desert tableland soil. To the degree that the soil surveyor's entities comprise an integration of the geographic associates, they may be considered as geographic types. However, they would differ from the Geographers' entities because, rather than being based on the knowledge of pedology

and the other basic sciences, they have been employed as a source of pedological information.

Soil workers have attempted to study, and rationalize, these geographic types by considering their relationship to climate, lithology, topography, and vegetation. It is doubtful if this is logically defensible since its geographic associates, (climate, lithology, topography, and vegetation) are already a component of every geographic type. To be studied in relation to its geographic associates a soil must first be recognised as a separate entity, and this can best be done under the discipline of the pedologic concept. But soils which have persisted through several climatic phases will have developed under several assemblages of geographic associates; and they will therefore, not be understandable in relation to their present site conditions alone, but only when their history is considered too.

A parallel attempt to rationalize the geographic types has been made by the Ecologist (Major 1951, Costin 1954), with the recognition of the ecosystem, and its dependent and independent variables. This approach also is only tenable if the present geographic associates are the only ones which need to be considered, i.e. if the system is monogenetic and does not contain dependent material from earlier systems. In the absence of proof of monogenesis, the geographic types, in spite of their apparent usefulness, are not amenable to rationalization. They are essentially empirical because of the relevance of their history to their comprehension, and because of the improbability that enough evidence remains for this history to be fully discovered.

Much of the soil work (primarily soil surveying) of the last thirty years has been done under the influence of the geographic concept, though it is clear that many of the logical problems mentioned above have not been recognised. In spite of these reservations, the work has served a useful purpose in simplifying the complexity of landscapes.

Though the geographic types, and hence the type areas, are empirical, they do divide landscape into manageable units, and though these areas are variable to a degree, they present a unity which could be evaluated in terms of the average and the range of various properties of significance. They have provided a basis for the planning and use of many areas. They have the merit of being comprehensive since they include soil, climatic, lithologic, topographic, and botanical data; and hence they may be better bases for assessing potential use, than a purely edaphic basis would be. However, being empirical, their evaluation cannot be extrapolated, and probably pilot trials are the only means of determining their use-value.

Unfortunately however, the geographic types have not only been used for this purpose, they have also been pressed into serving a pedologic purpose. It has been assumed that the geographic types, besides their geographic significance, must also have pedological significance and a chemical and physical significance too. It has been stated above that pedological significance can only be expected from soil samples of which the prior state, their unity as a soil system, and their time of origin is known. None of these requirements necessarily apply to the geographic types which have been chosen by the means discussed above. The method of selection does not prove whether the soil chosen is a single soil system, or a multiple one, whether it represents one age group or several, or whether it had a specific parent material or not. Notwithstanding these limitations, the attempt has been made in past years to develop the pedologic theme on the geographical basis. This seems clearly indefensible. Claims that the geographic types have a "fundamental" significance to pedology has had a most unfortunate effect on the development of soil knowledge.

It seems likely that the advancement of understanding of the geographic complex will come chiefly from the development of the basic sciences which pertain to it, and pedology may well be more helpful in this regard than the other sciences. This is so, because pedology is most likely to supply the chief lack in geographic studies—the historical component.

The geographic types have also, as is elaborated above, been pressed into serving the purpose of edaphic assessments. The distinctness of the geographic and edaphic themes, as

stated above, is such that their inter-actions would require specific research.

Discussion

As set out here, it seems that at least three themes of soil studies can be recognised, and that these are sufficiently distinct for each to require its own discipline. The purpose of each theme also is distinct. The purpose of the edaphic theme is the use of soils for crop growth, of the pedologic theme the understanding of soils as such, and of the geographic theme, a contribution to the understanding and mapping of the countryside. Though the different studies may all by chance apply to one piece of soil, their difference in purpose is the cause of their separateness. Their separateness is borne out by the fact that so many soil studies have failed to answer the edaphic question, though they have developed the geographic theme to considerable length, or again, in spite of the latter development, the pedologic theme is still largely unknown.

It appears that a failure to recognise the distinctness of the various themes, has not only resulted in a great amount of inconclusive work, but it has also prevented the normal development of certain lines of investigation, since these have been deemed to be covered by existing studies. A clearer statement of the separate themes may facilitate profitable work in each. It is likely too, that many of the difficulties concerning the classification of soils, arise in part from this multiplicity and confusion of themes.

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POTATO BREEDING IN NEW SOUTH WALES

R. J. JESSUP

The desirable characteristics of potato varieties for New South Wales, and the problems involved in obtaining these, have been outlined by Carroll (1951). The agronomic requirements are that the yield should be as good as or better than standard varieties, with a high percentage of marketable tubers. The tubers should be of good number, of medium size, and shallow eyed. They should have a tough skin which will stand storage and transport. The flesh should be white, mealy, and of good flavour.

Diseases that must be considered of importance in the breeding program are late and early blights, common scab, leaf roll, and the X virus. Due regard must also be paid to the possibility of obtaining resistance to the potato moth, which is the most serious insect pest of potatoes in New South Wales. For this reason, tubers of a new variety should be set deeply enough to escape moth injury.

The first work of strain selection was commenced at Glen Innes in 1929 by Macindoe. He was concerned with isolating better yielding and improved strains of Factor, then almost exclusively grown in New South Wales. Later work saw the instigation of a planned program to improve existing varieties by hybridization and selection.

As a result of this work, five varieties have been released by the New South Wales Department of Agriculture. The first of these, Monak and Adina, are late maturing high yielding varieties, with good field resistance to early and late blights, good cooking quality, and good agronomic qualities. Crana, the next variety released, is an early maturing red skinned selection, with excellent cooking quality, good yield, and good agronomic qualities, but with no disease resistance. Then came Awaba, a smooth white skinned variety, with good field resistance to late blight and good market quality. Walanga, the variety most recently released, is very late maturing, high yielding, with excellent field resistance to late and early blights. The acreage sown to this variety is increasing quite rapidly.

The varieties most commonly grown in New South Wales now are the United States introductions Sebago and Sequoia, which comprise about 65-70 per cent. of the total acreage. The early maturing Katahdin, Exton and Mainguy find favour particularly in coastal areas and in irrigated crops.

The Present Breeding Program

The provision of a large heated glasshouse at the Glen Innes Experiment Farm three years ago produced a marked change in the scope of the program.

Till the erection of this glasshouse, all work was done in the field at Glen Innes, so that crossing, which requires quite specialized climatic conditions to be successful, was a most haphazard affair. Selection for resistance to diseases in the seedling population depended entirely on the occurrence of a natural epidemic.

With the improved facilities, all crossing is now done in the glasshouse. This means a tremendous saving in time, and also a much greater percentage of successes. Detailed testing of seedlings for resistance to diseases, particularly late blight, virus X and common scab, can now be undertaken on quite a large scale. So the program has been

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expanded to cover a lot more territory, and should have greater possibilities of success.

Crossing

Each year, during the spring and autumn months, at least 60-70 crosses are made in the glasshouse at Glen Innes. So far parental material has consisted mainly of Scottish and American disease resistant introductions together with some of our own locally adapted seedlings and varieties, a few of which are pollen fertile.

Since the adoption of the method of sowing potatoes on bricks as a stimulant to flowering (Thijn 1954), the number of successful crosses, and the amount of true seed produced, has been substantially increased. Briefly, the method is as follows. The potato tuber is planted on a brick in a box and covered with a mound of sand. A string trellis is erected along the line of boxes, and when the plant has grown high enough to be tied to the string, the sand is washed away from the tuber, leaving the tuber bare on the brick, with the roots running off the brick into the surrounding dirt. The formation of any young tubers is prevented by continually breaking off of the stolons. This has the effect of forcing the growth into the top part of the plant, increasing the quality of flowers, the duration of flowering, and the amount of pollen. By using this method of flower stimulation, in conjunction with the extraction and cold storage of pollen as suggested by King (1955), a plentiful supply of true seed can be produced with a relatively small number of plants.

Sowing True Seed

Three sowings are made each year in the glasshouse at Glen Innes, and after any necessary screening for disease resistance, the seedlings are transplanted to pots on the glasshouse bench and there grown to maturity. This method of seedling raising has only been used since 1955, and has proved to be quite efficient.

It has been difficult to obtain the quick and uniform germination so desirable when testing young seedlings for resistance to diseases. This was more particularly so with seed which had just been extracted from the seed ball. Various methods of improving and speeding up the germination of the seed were tried. The best, and simplest tried so far is the method suggested by workers in Iowa (Peterson et al 1952). Briefly it is as follows. The seed is placed on damp blotting paper in a petri dish, and the dish left on a glasshouse bench for three days and nights, the temperature fluctuating between 55°F at night and 80°F during the day. Even with seed extracted from the seed ball only four weeks previously, the germination is generally over 85 per cent. Another desirable feature is that a good uniform

TABLE 1

Percentage germination of treated and untreated seeds at various intervals after sowing.

Cross	No. of seeds	No. of days after sowing					
		7	8	9	10	11	16
Treated							
Sequoia x Cortland	157	0	20	35	59	86	98
Cherokee selfed	145	14	59	74	77	84	91
1928(e)2 x Adina	150	8	51	65	69	82	90
Saranac x Cherokee	72	53	79	85	90	90	90
Untreated							
128 x 11-79	150	0	0	9	15	20	43
Cherokee selfed	103	0	0	10	33	39	50

germination can be obtained only twelve days after sowing the seed. Table 1 shows typical results gained with some of the seed. Results with unincubated seed are shown for comparison. Each lot of seed was extracted from the seed ball five weeks before sowing.

The seed is sown directly from the dishes to the seed boxes in inch squares, and the boxes covered with glass until the germination is almost complete. Then, after screening for disease resistance where applicable, the seedlings are transplanted to six inch pots and grown to maturity in the glasshouse. The glasshouse is fumigated at intervals with "Systox" or nicotine to prevent aphid infestation and so ensure virus free stocks. This method of seedling production has almost completely replaced the older method of transplanting to the field under irrigation.

Only a small amount of selection is done from the glasshouse pots, rejecting only those which show obvious agronomic faults such as long tubers and stolons and deep eyes. The largest tuber from each pot is kept, each line being bulked for ease of storage. The selected tubers are planted at a substation adjacent to the Glen Innes farm, using irrigation when necessary.

Each line is grown in increasing quantities at the substation till the fourth year, when the best fifty are grown in a preliminary yield trial. Each line is planted in 20 hill plots with four replications. This trial is planted in a typical red potato soil on a neighbouring farmer's property. At this stage, specific gravity readings are also taken on all lines, in order to obtain a quick and reasonably accurate estimation of cooking quality. Most workers agree that specific gravity is the best criterion of cooking quality short of actual cooking and tasting by a panel. A high specific gravity is taken to mean a high percentage of starch, and good culinary quality.

After any line has given a satisfactory performance in this trial, it is sent to the Orange district on the Central Tablelands, where it is planted on a co-operating farmer's property, increased, and finally tested in district yield trials which are carried out by district agronomists in about twenty different potato growing areas of New South Wales.

Breeding for Disease Resistance
Late Blight

Though late blight (*Phytophthora infestans*) is perhaps not as serious a threat in New South Wales as in other countries, it causes some losses every year, and in some years becomes a serious problem. During the 1955-6 season, when a fairly severe blight epidemic occurred —particularly in the tableland areas—the high field resistance of the new variety Walanga proved of immense value to those who had planted it as very small losses were suffered with this variety. Other more susceptible varieties went down very quickly before the disease, and severe losses were incurred in many areas.

Obviously then, breeding for resistance to late blight must be a primary consideration in the program. Since the erection of the glasshouse and the adoption of improved techniques, it has been possible to carry out large scale mass inoculation of young seedlings while still in the seedling boxes.

The simplest and most convenient method of testing the seedlings has been found to be that used by Keay (1954). A zoospore suspension of the fungus is prepared by placing slices of infected potato tubers in petri dishes lined with damp filter paper. Conidia are produced in about four to seven days and these are scraped off into distilled water and placed into a refrigerator for about two hours, when the production of zoospores should have begun.

The seedlings are kept in a humidity chamber for about 24 hours, then sprayed with the zoospore suspension, and left there for a further 24 hours. They are then removed, placed in a cool part of the glasshouse, and, after four or five days, when symptoms of the disease become apparent, are replaced in the humidity chamber to induce sporulation of the fungus on the leaves.

For use as a humidity chamber, light wooden frames are constructed, and clear plastic covers are made to fit over the frames. The top of the cover is made separately, so that it can be removed during inoculation and

while susceptible plants are being removed. The frame is then stood in a galvanised iron tray of water, the boxes of seedlings being placed on wooden blocks to keep them raised above the water and so prevent water logging.

Very good results have been obtained using this set up, and it has the special advantages of being very cheap, and causing no damage to the resistant seedlings. The frames as described, being light and easily handled, can be stored away when not being used, and do not take up space in the glasshouse.

So far in the blight inoculation work done at Glen Innes, mixed isolates of the fungus from various localities in New South Wales have been used. The results indicate that at the present, there exists only the common race of blight in the potato growing areas of this state.

During this testing work, the resistance of numerous introductions from overseas has been established. Some of those whose stated resistance has been proved are:
From Scotland; 914(a)91, 1928(e)2, 835(a)4, 885(4), 1521(c)3, and 1563(a)3.
From U.S.A.; Cortland, Pungo, Cherokee, and Merrimack.
From Germany; Aquila and 19162.

Numerous other resistant introductions are on hand but their resistance has yet to be proved.

Virus X (Latent Mosaic)

Latent mosaic was a fairly severe problem in New South Wales when the variety Factor was grown almost exclusively. However with the introduction and consequent popularity of the United States varieties Sebago, Sequoia and Katahdin, the disease became less troublesome.

Norris (1953) offers some figures which indicate how quickly the virus can spread. He noted that one line of Up to Date, originally free of virus X, had, in six years, reached a position where the crop was 41.5 per cent. infected. Infestations in other varieties were Sebago 2 per cent., Sequoia 4 per cent. and Saranac 5 per cent.

It does seem that virus X must be considered to be of some importance and that it would be desirable to produce a variety that is immune, or field immune, to the disease. Work is now in progress testing young seedlings that have in their parentage the American lines Saco, B595-76 or S41956.

Testing is carried out in the glasshouse where young transplanted seedlings are inoculated by hand, using the variety Up to Date as a source of inoculum. For an abrasive, necessary to allow the virus to gain entry into the leaf of the plant being tested, Hyflo super cel—a type of diatomaceous silica—is used. This was shown by Hutton (1951) to give equally as good results as carborundum, when incorporated with the inoculum at the rate of 1.0 per cent. His findings have been borne out by experience at Glen Innes.

The testing work is done in the spring and autumn months when, with cooler temperatures and lower light intensity, infection by the virus is easier to obtain and the symptoms are more definite. Bawden and Roberts (1947) have shown the effects of environmental conditions on the reaction of virus in plants. Their work showed that lower light intensity increased the susceptibility of plants, while higher temperatures tended to make some susceptible plants appear to be resistant.

The seedlings are inoculated after transplanting from the seed boxes to pots, when they are about six inches high and growing vigorously. Symptoms generally appear on susceptible plants within 14 to 21 days.

No differentation of strains of virus X has yet been attempted in New South Wales. The strain or strains taken from Up to Date as inoculum give a moderately severe systemic reaction on susceptible plants.

Virus Y

Virus Y has not yet appeared as a serious problem in New South Wales potato growing areas. As a consequence very little work is being done to gain resistance to it. The localised necrotic reaction as possessed by Hutton's seedling 11-84 seems to be the most easily attainable goal.

Leaf Roll

Leaf roll is probably the most important potato virus disease in New South Wales. However no worthwhile resistance has been

found in any of the seedlings or varieties in use here, except that in Bismark as described by Hutton and Brock (1953). Other resistant seedlings that have been introduced from overseas are B24-58 and X927-3 from U.S.A., Southesk from Scotland, and Aquila from Germany.

Due to the difficulty of handling large populations of seedlings in testing for leaf roll resistance, and to the limited facilities available here at Glen Innes, large scale testing cannot be carried out. However, it is hoped that by using as parents the known resistant material, and selecting on agronomic characters, some worthwhile degree of resistance may come to light.

Common Scab

Common Scab (*Streptomyces scabies*) is fairly widespread in New South Wales, though many areas do not suffer severely from it. In some districts—particularly on the Central Tablelands—it could become a limiting factor in potato production. As a consequence, part of the breeding program at Glen Innes is focused directly on the production of scab resistant varieties.

Numerous resistant varieties have been introduced from overseas countries, among them being Menominee, Seneca, Yampa, Ontario, Cherokee and Plymouth, all from the United States. These have all shown good scab resistance in field tests, but have not been suitable agronomically. Menominee is too prone to tuber defects, while Yampa, Seneca and Cayuga are not sufficiently high yielding. Ontario is often affected badly with brown fleck and is not of good cooking quality. Cherokee, a more recent introduction, produces too many off types.

The European variety Ackersegen has shown the best resistance of any introduced commercial variety but its yellow flesh and roughness make it unacceptable to commercial growers here. Emilia, a *Solanum andigenum* seedling introduced from South America, has been shown in field tests to be very highly resistant to scab. Unfortunately the roughness of its tubers and other wild characters will prevent the immediate transmission of its high resistance into a commercial variety. It seems likely that really high resistance to scab must come from such a source as this because no resistant variety yet produced has shown as high a resistance as its parents —one of which, in most cases, has been the European variety Jubel. A wide series of crosses is being made with two *Solanum andigenum* lines to investigate the possibility of obtaining a high resistance.

Until recent years the standard method of testing seedlings for scab resistance was to grow the most promising advanced selections in a scab infested soil at Spring Hill, near Orange, on the Central Tablelands. This of course, must be the final test of a seedling's resistance, but a quicker and reasonably accurate method was needed for large scale testing at the seedling stage. The technique suggested by Schaal *et al* (1953), namely the use of ferric chloride offers a partial solution to the problem. The test depends on the fact that tubers of resistant varieties have a higher concentration of chlorogenic acid in the skin than do the tubers of susceptible varieties. A simple ferric chloride test for phenolic compounds is used by placing a few drops of 2 per cent. ferric chloride solution on a tuber, and macerating the skin under the drops with a stainless steel knife. Resistant tubers, with the higher concentration of chlorogenic acid, develop a dark green colour in the ferric chloride solution while susceptible ones develop no colour or a very pale green.

This test has been used fairly extensively at Glen Innes and, while it would not be possible to accurately determine degrees of resistance, it does appear to be quite effective in removing susceptible seedlings from a progeny bred for scab resistance.

Probably the best test yet devised for screening seedling populations for scab resistance is that suggested by Dykstra (1956) of growing the young seedlings in vermiculite infected with the scab organisms. The test has been attempted at Glen Innes using scab infested sand and soil, but infection was not uniform, and conditions were generally not suitable for the development of the disease. A small scale preliminary trial with vermicu-

lite indicates that this method will be quite successful once the operator masters the technique involved. As Dykstra claimed, scab lesions can be detected on tubers a little larger than a pea.

Conclusion

Results so far have indicated that in the near future, we will be able to release varieties with high resistance to some of the major potato diseases in New South Wales.

Several advanced seedlings that have been tested to be immune to the common races of late blight in New South Wales are shortly to be tested in district variety trials. Some degree of scab resistance has come to light in the variety Awaba (Pontiac x Katahdin) and the red skinned seedling S2680 (Gold Coin x Saranac), but it is not of as high an order as that of the introduced varieties.

Work on other diseases has only just commenced, so no definite results are yet available from this work.

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Ground Spray Treatments for Control of Banana Beetle Borer *(Cosmopolites sordidus Germ.)*

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The value of cap-baiting as a method of control for banana beetle borer (Cosmopolites sordidus Germ.) is reviewed and the conclusion reached that it is relatively ineffective.

An experiment in which the efficacy against Cosmopolites of dieldrin, aldrin and lindane ground sprays was compared with cap-baiting is described.

Excellent control of Cosmopolites was obtained with both aldrin and dieldrin ground sprays but lindane ground sprays and poison cap-baiting gave poor control.

The single aldrin and dieldrin treatments retained their effectiveness for the duration of the experiment, namely 10 months. In this time 101 inches of rain were received. The Cosmopolites population was reduced to such an extent that the possibility of eradication cannot be overlooked.

For forty years banana beetle borer (*Cosmopolites sordidus Germ.*) has ravaged banana plantations in New South Wales. Compulsory control measures and quarantine regulations have limited the spread of the pest, but over the years it has caused heavy losses in the Tweed, Brunswick and Richmond River districts.

This paper analyses existing control measures and describes a recent ground spray control experiment carried out in the Tweed River district. In this experiment the control obtained with dieldrin and aldrin ground sprays was of such a high order that it appears that banana beetle borer may in the future be relegated to the status of a minor pest.

Review of Control Measures in N.S.W.

In 1936 a New South Wales Government Gazette made it compulsory under the Plant Diseases Act to control Banana Beetle Borer. The method of control specified was to cut and treat spent banana stems in such a way that the residual butts and the basal six inches of the pseudostems were made into poison baits.

Paris green, mixed with flour at the rate of one part paris green to twenty parts of flour, was the prescribed poison. The residue of the pseudostem was to be destroyed by longitudinal slashing.

Paris green was the only poison recommended for cap-type baits until 1948 when DDT was included as an alternative. Since then, the list of alternatives has grown and the Plant Diseases Regulation covering this pest has been amended on a number of occasions to include DDT, BHC, BHC plus DDT, aldrin and dieldrin.

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Effectiveness of Cap-Type Poison Baits

The Australian literature contains scanty quantitative evidence of the effectiveness of cap-type baiting.

Wallace (unpublished data 1933-36) was unable to obtain a notable reduction in Beetle Borer numbers even when poisoned baits were placed at every stool in experimental plots twice within a month. In this work definite numbers of beetles were introduced into enclosed plots, where elaborate precautions in the way of vertical galvanised iron barriers were erected to prevent the entry or escape of beetles.

J. L. Froggatt (1928), who first tested the paris green—flour mixture, stated in his later work that it had been used under plantation conditions with satisfactory results, but no numerical record is given of the reduction in Cosmopolites population achieved.

Weddell (1934) suggested, in addition to the paris green-flour cap-bait, a supplementary poisoning system whereby the cut surfaces produced in the desuckering process were converted into poison baits by dusting with paris green-flour, 1 : 6. No figures are given.

More recent work has not clarified the position. BHC, DDT and combination dusts of the two insecticides, tested in cap-type baits in the Murwillumbah district in 1948-49 were concluded to be superior to paris green-flour when larger numbers of beetles were collected from them.

The numbers of beetles taken at poison baits may represent only a fraction of the beetle population in the plantation. They are not necessarily indicative of an effective control measure. Indeed, baiting may tend only to lessen the Cosmopolites population without effectively controlling it. Many writers have asserted this and observations in the Murwillumbah district support the theory.

At the Duranbah Demonstration Plot, Tweed River, poison cap baiting has been used continually for many years. In spite of this, the numerous plants which are uprooted annually by wind are invariably infested with Cosmopolites. The numbers of beetles trapped at the baits have not decreased significantly in recent years. If baiting were effective it is reasonable to expect Cosmopolites numbers to have declined at baits and less damage to be recorded.

Finally, a pre-requisite of effective baiting is a plentiful supply of bait material. This condition is not met under New South Wales growing conditions where individual plants mature only one bunch approximately per year and therefore, provide only one residual butt for baiting. This means that the plant is only protected from Cosmopolites while the single bait is effective, a period which does not exceed one month. In effect, therefore, the plant is unprotected from Cosmopolites attack for the greater part of its growing period.

This brief review, covering the most significant Australia work, suggests strongly that cap baiting is a palliative only. It is of interest to record here that evidence obtained in the course of the experimental work described, confirmed this suggestion.

Insecticides Applied to the Growing Plant

Insecticides applied to the basal parts of plants and the adjacent soil have been tested by numerous workers. Wallace (unpublished data 1933-36) found that treatment of the butts and the soil around the butts of plants with lead arsenate or sodium arsenite sprays or with paris green or sodium fluosilicate dusts was relatively ineffective.

BHC dusts were found by de Toledo (1952) to prevent Cosmopolites attacking banana corms when applied to the soil at monthly, or two monthly, intervals. They were considerably more effective than dusts of chlordane or toxaphene.

Villardebo, Merny et al (1951) showed that both BHC and parathion were effective against Cosmopolites but they leached or decomposed too quickly for practicable control.

More recently promising control has been obtained with dieldrin and, or aldrin. Experiments in the Canary Islands showed that plants could be protected for eleven months with dieldrin soil and butt treatments of approximately 2 lb. actual dieldrin per acre. Simmonds and Simmonds (1953) found that an annual application of dieldrin-aldrin mixture at a rate of approximately 2 lb per acre could be used to protect plantains from Cosmopolites attack.

Figure 1—Pseudostem cut transversely into slices approximately three inches thick.

Figure 2—Transverse slices (or trap) in position at the base of a central plant in a plot. Four slices were placed in each plot at every trapping.

Figure 3—Slice covered with leaf debris to prevent rapid desiccation and to assist attraction of borers to traps.

TWEED RIVER EXPERIMENT

In October 1955, an experiment was initiated at Condong, Tweed River, New South Wales, to determine the effectiveness of a number of different ground and butt spray treatments against Cosmopolites and to compare these treatments with the prescribed control measure of poison cap-baiting.

Site

The section of the plantation used for the experiment was situated on a hot, northerly slope at an elevation of approximately 300 feet. It had been completely neglected for eighteen months. Weed and grass growth were prolific. Desuckering, removal of dead leaves and destruction of spent stems had not been carried out. Both stems and suckers were very numerous and congested and their crowns were exposed several inches out of the ground. Water suckers had been allowed to accumulate around parent plants and were dying from Cosmopolites infestation and lack of nourishment. Dead leaves, hanging from maturing plants, partially covered suckers and obstructed normal unfurling of leaves. Fallen stems which littered the ground had not been slashed and standing spent pseudostems from which bunches had been cut had been left to rot in situ. Fertilisers had not been applied and no form of pest and disease control had been practised.

Cosmopolites Infestation

The whole of the experimental block was heavily infested with Cosmopolites. In addition to water suckers whose corms and stems were completely tunnelled, maturing plants and advanced suckers were loose in the ground from the heavy infestation, were easily pushed over, and were wont to fall over in the slightest breeze. Adult beetles were found tunnelling in stems up to the throats of plants and corms were completely riddled with larval tunnelling. Few plants were reaching maturity and bunches were small and the fruit was of poor quality. Rotting pseudostems on the ground and plants that had fallen over were tunnelled extensively and heavily infested.

On three sides of the experimental block unproductive bananas had been dug out some twelve months previously and the stems left to rot on the ground. These stems were heavily infested with all stages of Cosmopolites. Thus, in addition to the heavy infestation within the experimental area there was a ready source of infestation nearly all around the experimental block.

Cultivation and Sanitation

In September, seven weeks before the experimental block was treated with insecticides, weeds and tall grass were brushed and the whole area hand-cultivated. Weed control sprays were applied and in mid-October, fertiliser applications made. In November, plants were stripped of dead leaves, trash was moved away from the crowns of plants, rotting stems on the ground were slashed longitudinally and exposed to the sun and desuckering and removal of useless and superfluous plants were carried out.

At this juncture the four plots to be treated with the standard BHC cap-bait were selected at random and the cultural and sanitation practices referred to above were carried out in them with the exception that enough superfluous plants were left to ensure that every plant would receive a poison bait when the treatments were applied.

Experimental Layout

In November, when the experimental area was considered to have reached a state of fairly normal sanitation it was divided into twenty plots—each plot consisting of approximately 25 stools. Plot boundaries were marked with rope. The five treatments, to be replicated four times, were then allocated to the twenty plots at random. The four plots of the cap bait treatment had already been randomly selected.

Assessment of Population before Treatment

In October and November two series of trappings were carried out to assess the Cosmopolites population in the 20 plots before they received insecticidal treatments (Table 1). These trappings, which became the standard method of assessing the borer population throughout the experiment, consisted of placing four transverse slices of freshly cut pseudo-

TABLE 1

Pretreatment trappings for assessment of beetle borer population.

Treatment	No. Adult Cosmopolites taken at Traps (16 traps per treatment per month)		
	Oct.	Nov.	Mean
Aldrin	156	258	207
Dieldrin	158	270	214
Lindane	220	268	244
Cap bait	177	379	278
Control	200	248	224

stem at the bases of central plants in the plots and covering them with leaf debris. The traps were examined three times at regular intervals over a period of two weeks and counts were made of beetles attracted to them. The traps were then broken up and dispensed with. Beetles found at the traps were liberated in the plots from which they were trapped. This method is essentially the same as that used by Wallace and in the absence of a direct method of collecting every beetle from the soil and the plant it provided a fairly satisfactory method of assessing the Cosmopolites population.

Figure 4—Banana plants ready for ground and butt sprays. Note that dead leaves have been removed from pseudostems and trash has been cleared from bases of plants.

Figure 5—Dieldrin ground and butt spray being applied with a knapsack spray pump. Only the basal twelve inches of plants and the twelve inches of soil are treated.

These trappings confirmed the observation that the Cosmopolites population was high throughout the experimental area. There was little difference in the total number of beetles trapped in the five series of plots except in the second trapping when abnormally large numbers of beetles were collected in the plots to be baited. These plots it will be recalled, were not desuckered and freed of superfluous plants as the rest of the experimental area was and it is believed that beetles migrated into them.

Application of Treatments

On November 24, when the second series of trappings had been finalised and the assessment of the adult Cosmopolites population concluded, the insecticide treatments were applied. Of the five treatments, three involved spraying the butts of the plants and the soil immediately adjacent, one was a poison cap-bait treatment while one was a "control", receiving no treatment at all.

Treatments

1. Lindane 0.03 per cent gamma isomer ground and butt spray.
2. Aldrin 0.1 per cent ground and butt spray.
3. Dieldrin 0.05 per cent ground and butt spray.

TABLE 2

Total No. adult Cosmopolites taken at all traps in course of experiment.

Treatment	Pretreatment trappings Mean No.	After treatment trappings. No. months after treatment.								
		1	2	3	4	6	7	8	9	10
Aldrin	207	11	15	10	21	53	67	8	6	5
Dieldrin	214	12	2	18	13	67	143	23	21	28
Lindane	244	150	275	325	243	257	382	72	77	213
Cap bait	278	88	179	186	163	214	267	68	116	232
Control .. .. (No Treatment)	224	130	205	205	153	187	300	59	75	181

4. Cap-bait using 4 per cent BHC dust.
5. Control—no treatment.

The ground and butt spray treatments were applied with a knapsack spray pump to the lower 12 inches of the stem and the adjacent 12 inches of soil around the stem of every plant and sucker in the respective plots at the following rates:—

1. Lindane—8 ozs. active ingredient per acre.
2. Aldrin—2 lb. active ingredient per acre.
3. Dieldrin—1 lb. active ingredient per acre.

Every stool in the cap-bait plots received a poison bait of 4 per cent BHC dust and therefore, initially, this treatment was directly comparable with the ground and butt spray treatments. In addition, however, after the first wholesale cap-baiting, spent stems from which bunches were cut, were cap-baited as they became available.

All plots received in addition to any spray or poison bait treatments, cultural attention and a uniform programme of sanitation throughout the course of the experiment. This consisted of:—

A. Cutting all spent stems longitudinally and then transversely into four sections and exposing them to the sun to dry out quickly.
B. Destruction of all fallen stems and corms by cutting up.
C. Chipping to control weeds.
D. Stripping of dead leaves from pseudostems.
E. Desuckering and removal of water suckers.
F. Fertiliser applications.

Results

The effectiveness of the treatments was determined by trapping as previously described. A treatment was considered effective if a dearth of live beetles was collected at the traps placed in the plots after the insecticides had had time to take effect.

As pre-treatment trappings had been made the level of the Cosmopolites population was known and any population fluctuation could be measured.

At intervals of approximately one month, traps were placed in each plot and counts made of the live beetles trapped. The traps were placed in a central position in each plot so that beetles trapped could be considered individuals of the plots from which they were recorded and not migrants from adjacent plots. The month by month totals of beetles taken from the five series of plots following treatment are given in Table 2 together with the mean pre-treatment numbers of beetles from each.

Discussion

Both the dieldrin and the aldrin ground spray and butt treatment caused remarkable reductions in Cosmopolites numbers. The initial drop in population of approximately 94 per cent was striking evidence of an effective contact action but equally notable was the residual effectiveness of the two materials in the tenth month after treatment when the population was of the same low order as in the first month.

TABLE 3

Mean No. Beetles per plot one month after application of treatments.

Treatment	Mean Adjusted	Mean Transformed
Aldrin	2	0.512
Dieldrin	3	0.610
Cap bait	18	1.269
Lindane	31	1.500
Control (no treatment)	27	1.449
Minimum significant difference P = .05.		0.411

The counts of beetles for the first month are shown in Table 3. The figures have been adjusted by covariance on the counts per plot and prior to treatment. A logarithmic transformation was used and both the log. values and the transformed means are shown. The aldrin and dieldrin treated plots had significantly less ($P \leqslant .05$) beetles than the other plots at that time.

It can be seen from Table 2, which summarises all trappings, that this difference continued throughout the experiment.

The temporary increase in numbers which occurred in the sixth and seventh months may appear superficially to indicate reduced efficiency of dieldrin and aldrin but observations showed it was caused by a major adult emergence in May and the final trapping in the tenth month indicated that this emergence had been well controlled by the two insecticides in the intervening months.

This last trapping, which was carried out in September, also showed that Cosmopolites had returned to its high pre-winter levels in cap-bait, lindane and untreated plots and remained low in dieldrin and aldrin plots—proof of the continued residual toxicity of these two materials. Indeed, the reduction in Cosmopolites effected by the combined contact and residual action of dieldrin or aldrin was so great under the exacting conditions of the experiment that the possibility of eradication of this pest under more favourable conditions should not be overlooked.

The fact that significant reductions in Cosmopolites numbers were not recorded in the control plots in the ten months of the experiment was evidence that rigid field sanitation alone is not adequate against this pest. While sanitation is undoubtedly an essential routine practice the results showed clearly that the use of an effective insecticide (either dieldrin or aldrin) is the most important factor in Cosmopolites control.

None of the other treatments reduced borer numbers significantly at any time. The lindane ground and butt spray treatment proved completely ineffective and a very poor result was obtained with the poison cap-baits. In view of the fact that every stool clump received a poison bait initially the control obtained was surprisingly low. However, as stated previously, the plantation had been neglected for a long time and consequently fewer bunched plants than usual became available for baiting. Nevertheless, enough baits were set out for control to be obtained if the treatment was efficient.

An interesting feature of the control achieved with dieldrin and aldrin was the excellent residual toxicity of these materials under high rainfall conditions. In the eleven months of the experiment (November 1955, to September 1956) 101 inches of rain were received including 16 inches in December, 43 inches in February and 10 inches in both March and May. Average annual rainfall for the area is approximately 70 inches. Both materials therefore, may be expected to be effective for at least a similar period under normal rainfall conditions.

Although the experimental area was situated on a steep mountain-side there was little leaching or other movement of either of the effective insecticides away from the point of deposit at the bases of the plants. Indicative of this was the fact that, despite the randomised block design of the experiment, trap counts were always high in lindane, cap-bait and control plots and low in adjacent aldrin and dieldrin plots.

This raises the question of the necessity of concerted control measures against Cosmopolites by all growers in a locality if dieldrin or aldrin are used. The data presented here point strongly to the fact that a grower using either of these two materials can expect no

trouble from Cosmopolites migrating from a neighbouring untreated plantation.

In the course of the experiment records were taken of the number of plants that were blown over. Normally losses of plants from wind, following an initial weakening of the underground parts by Cosmopolites, are considerable in northern New South Wales, even in well looked-after plantations. The plantation was exposed to northerly winds, which at times reached considerable velocities. Examination of uprooted plants revealed in all cases heavy Cosmopolites infestation.

The number of stools uprooted in each treatment was:—

Aldrin	0
Dieldrin	1
Bait	11 plus 3 leaning over.
Lindane	13
Control	11

This record confirmed the observation that in the absence, or relative absence, of Cosmopolites, following dieldrin or aldrin ground spraying, plants became very firmly rooted in the ground and better able to withstand the elements.

The fact that small larvae, late instar larvae, pupae, and adults, of Cosmopolites are met with abundantly in the field at any time of the year indicates that there is no brood behaviour of this species. In the course of the monthly trappings, however, two major adult emergences were recorded. In mid-January and again in mid-May a large percentage of beetles collected at traps were the immature, red to reddish brown beetles that had recently emerged from the pupal stage. The reddish colouration lasts for about two weeks after the beetle transforms from the pupa, gradually darkening during this time to dark brown and finally to black. The period mid-January to mid-May indicated a complete life cycle of approximately four months, which is somewhat longer than expected for the lower Tweed River.

An unusual predator of Cosmopolites was found on a number of occasions under the traps placed on the ground at the foot of the banana plants. It was the blue planarian worm *Geoplana caerulea,* a native species of flatworm generally found under logs, bark, etc. in moist situations and common in banana plantations.

By means of an evertable proboscis the worm would grasp the insect, suck out its body fluids and leave the chitinous exoskeleton intact.

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The statistical analysis was carried out by Mr. P. E. Russell, Biometrician, Department of Agriculture, New South Wales.

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Effective Nodulation Vs. Bag Nitrogen in Growth of Subterranean Clover

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Ineffective nodule bacteria were heavily inoculated into soil naturally containing effective strains. By this means, subterranean clover plants were induced to perform like non-legumes, and an assessment of the improvement due to ammonium sulphate could be made. The proportion of plant nitrogen from air and by nitrogen fixation could be estimated for different levels of ammonium sulphate. Effective nodulation was found to permit about the same growth and nitrogen per plant as could be obtained with 4 cwts. ammonium sulphate per acre.

It was also found that marked improvement in growth can be induced by the presence of very few effective nodules on plants whose roots bear a very large number of ineffective nodules, hence the percentage of plants bearing effective nodules is a useful guide to the nitrogen fixing potential of the treatment.

In situations where a high proportion of effective strains of nodule bacteria are prevalent in soil, it may be exceedingly difficult to test their contribution to plant nitrogen in the field. Virtanen and Saubert von Hausen (1952) have demonstrated that under such conditions an assessment of the relative proportion of nitrogen obtained from air and soil can be made by inoculating pea plants with an ineffective strain. On subsequent planting out into soil containing effective rhizobia, no effective nodules formed, and growth was due entirely to soil nitrogen. Plants untreated with ineffective strains showed normal nodulation and the improved growth was presumably due to nitrogen fixation.

Such a situation exists at the McGarvie Smith Institute of Animal Husbandry at Badgery's Creek. Mr. F. Crofts found that field tests showed no response to clover inoculation although nitrogen was known to be strongly limiting grass growth in second-year mixed pastures.

In order to check the contribution made by effective nodulation to growth of clovers a modification of Virtanen and von Hausen's method was employed.

Method

Soil cores (Vincent, personal communication) proved a useful means of applying this test. In the ineffective treatment the soil cores were very heavily inoculated, each with 10^{10} cells, before direct sowing with surface sterilised Tallarook seed. This treatment was repeated at eight weeks. In other treatments the soil was not inoculated, and surface sterilised seed was sown either uninoculated,

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or inoculated with SU298 or a commercial peat culture.

Ammonium sulphate treatments were superimposed on the inoculation treatments. The ammonium sulphate was watered on at weekly intervals giving the equivalent of applications of 0, 1 and 4 cwts per acre every six weeks. Six complete replicates of each treatment were included.

Results

Mean wet weights per plant were closely correlated with dry weights, which are shown in Table 1, together with total nitrogen values, estimated by the Kjeldahl method. The percentage of plants bearing any effective nodule is also shown in Table 1.

Analysis of variance performed on the logarithmically transformed data of dry weights

TABLE 1.

Ineffective vs. Effective or Natural Inoculation of Subterranean Clover Treated with Different Levels of Ammonium Sulphate.

INOCULUM	LEVELS OF AMMONIUM SULPHATE (CWTS/AC) 0	1	4
INEFFECTIVE			
Dry wt. per plant, mg.	65	84	150
RANGE	37-85	56-105	117-224
Total N. per plant, mg.	1.3 (2.0%)	1.63 (1.9%)	3.51 (2.3%)
RANGE	0.81-1.88	1.08-2.11	2.71-5.27
% plants with effective nodules	19.0%	8.7%	6.3%
RANGE	0-41%	0-17%	0-18%
NIL			
Dry wt. per plant, mg.	129	130	162
RANGE	100-150	82-148	129-210
Total N. per plant, mg.	3.40 (3.1%)	3.8 (2.9%)	4.88 (3.0%)
RANGE	3.13-3.89	2.08-5.49	3.87-6.90
% plants with effective nodules	63.2%	87.3%	85.7%
RANGE	50-74%	73-100%	75-100%
EFFECTIVE			
Dry wt. per plant, mg.	137	157	142
RANGE	116-175	130-211	127-157
Total N. per plant, mg.	4.13 (3.0%)	4.87 (3.1%)	4.36 (3.1%)
RANGE	3.41-4.58	4.11-5.60	3.85-5.01
% plants with effective nodules	95.3%	97.7%	89.7%
RANGE	85-100%	91-100%	74-96%
COMMERCIAL			
Dry wt. per plant, mg.	124.0	132.0	155.0
RANGE	113-141	76-180	118-213
Total N. per plant, mg.	3.52 (2.8%)	3.58 (2.7%)	4.21 (2.7%)
RANGE	3.16-4.13	2.85-5.49	2.73-5.48
% plants with effective nodules	89.0%	82.1%	76.4%
RANGE	73-100%	44-100%	32-93%

TABLE 2

The proportion of nitrogen per plant derived from soil and from air.

	Level of ammonium sulphate—cwt/acre 0	1	4
1. From Soil			
Ineffective with no effective nodules	0.93 mg. N.	1.86 mg. N.	3.49 mg. N.
2. From Air			
Mean effective treatments minus 1	2.95 mg. N.	2.22 mg. N.	0.66 mg. N.
Ratio Air Nitrogen/Soil Nitrogen	3.17	1.19	0.19

showed no significant variance ratios for main effects, either inoculation or nitrogen level treatments. A highly significant ($P < .001$) level of probability for the inter-action between inoculation and nitrogen levels, brings out the differences due to ineffective inoculation at low levels of nitrogen. A "t" test shows that both 0 and 1 cwt per acre with ineffective inoculation were significantly lower than all other means ($P < .001$) and 0 cwt was significantly lower than 1 cwt for the ineffectively nodulated sets ($.05 > P > .001$). The highest (nil inoculum, 4 cwt sulphate of ammonia) minus the lowest (commercial, 0 nitrogen) of all other means just reaches the 5 per cent level of probability that the difference is not due to chance, otherwise all means fall into the same population.

The picture with total nitrogen per plant data was very similar. An analysis of variance performed on logarithmically transformed data showed significant variance ratios for inoculation treatments (attributable to the set with the ineffective inoculum) and for interaction of inoculum x nitrogen level. Again the significant differences were 0 and 1 cwt ammonium sulphate with the ineffective inoculum, with differences between the highest and lowest means barely reaching a 5 per cent level of probability.

Artificial inoculation with effective strains produced no significant improvement in growth or total nitrogen per plant, and examination of root systems indicated that a high proportion of uninoculated plants bore effective nodules produced by effective local strains. In all such instances there was no significant response to ammonium sulphate, in weight or nitrogen per plant. These provide a marked contrast to the plants inoculated with the ineffective strain which generally behaved like non-legumes in their response to bag nitrogen.

No improvement due to artificial inoculation could be detected and it may be assumed that the naturally occurring strains are highly effective on Tallarook.

In this soil good natural nodulation permits about the same growth and nitrogen fixation of Tallarook as could be obtained with 4 cwt of ammonium sulphate per acre—applied every six weeks. Ineffective nodulation does not seem to be parasitic; the slightly lower total nitrogen figure in the 4 cwt per acre sets due to ineffective inoculation is not significant.

The Proportion of Plant Nitrogen Contributed by Fixation

Plants from some of the soil cores which had been inoculated with the ineffective strain were entirely without effective nodules. The nitrogen values from these sets provide an estimate of the amount of nitrogen derived from the soil (Table 2, line 1.) An estimate of the amount of nitrogen from the air in the effective treatments may be calculated by difference (Table 2, line 2).

This estimate is, of course, based on the assumption that absorption from soil is preferred to fixation, and sets a minimum for the amount derived by fixation.

Relation Between Plant Weight and Number of Effective Nodules per Plant.

A few of the plants inoculated with the ineffective Rhizobium developed effective

TABLE 3.

Wet weights (gms.) of Selected Plants with 0-3 Effective Nodules.

LEVEL OF AMMONIUM SULPHATE (cwt./acre)	NUMBER OF EFFECTIVE NODULES PER PLANT											
	0			1			2			3		
	Mean	No. Plants	Range	Mean	No. Plants	Range	Mean	No. Plants	Range	Mean	No. Plants	Range
0	0.33**	16	0.1-0.5**	1.03	3	0.5-1.95	0.85	4	0.55-1.2	1.37	3	0.9-2.0
1	0.67**	13	0.4-0.95**	1.38*	2	1.35-1.4	1.35	2	1.2-1.5			
4	1.37	12	0.3-2.5	2.14x	4	1.9-2.4						

**Probability < .01 that means are different. *Probability < .05, > .01 that means are different.

Variance of differences calculated from square root of the sum of the pooled variances × "t".

nodules. These could nearly always be distinguished at the 0 and 1 cwt. levels of ammonium sulphate by their improved growth and dark green colour, but did not begin to show up until late in the experiment.

Marked improvement in growth can be induced by the presence of very few effective nodules on plants whose roots bear a very large number of ineffective nodules; This is shown by the weights of selected plants shown in Table 3.

The response to ammonium sulphate was marked in the absence of effective nodules; that it was still observed with one or two effective nodules is probably due largely to the delayed initiation. On the other hand an increase in the number of large nodules from one to three does not accord any improvement. These weights compare well with effectively nodulated plants where 1.35, 1.18, 0.85, 0.71, 1.30, 1.15 gm. mean wet weights were recorded for plants respectively bearing 1, 2, 3, 4, 5 and 6 large nodules (4 cwts. of ammonium sulphate.)

This observation supports the finding of Jenkins, Vincent and Waters (1954) that the percentage of plants bearing effective-looking nodules can provide a useful guide to the nitrogen fixing potential of the treatments under conditions where soil nitrogen is limiting.

Acknowledgments

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The Induction of Mutation in Subterranean Clover by X-Irradiation

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Dormant, Dwalganup strain, subterranean clover seeds were X-rayed with doses of 0-120 kr at approximately 10 kr intervals. Radiation effects in the first generation conformed to the usual pattern found in legumes, namely delayed but scarcely reduced emergence, distorted seedling growth, chlorotic mottling, and killing of young plants. Above 90 kr, few plants survived, the 50 per cent. survival dose for plants grown under good conditions lying at 60-70 kr. Mainly as a result of the small size of irradiated plants, the quantity of X_1 seed set fell to low levels at the higher doses. Storage of irradiated seeds for two years had a small deleterious effect on X_1 survival.

It appears that most mutant X_1 plants are chimerical for mutations, the mean X_2 family segregation from whole X_1 plants being 6.45 normals : 1 mutant. When chlorophyll mutations and obvious morphological aberrations were scored in the X_2 generation, mutation rates of up to 44 per cent. were obtained, from X_2 families with a mean size of 4.6, at the 67 kr dose level.

Twenty eight per cent. of all mutations scored were dwarf or small plants and 42 per cent. were chlorophyll mutations. No dose effect on the fertility of the mutants was revealed. Thirty one per cent. were fertile and viable, 41 per cent. semi-lethal or -sterile, and 28 per cent. lethal or sterile.

Some knowledge of the reaction of subterranean clover—*Trifolium subterraneum* L.—to ionizing radiations must be obtained if such radiations are to be used in breeding programmes with this species. Several studies of irradiation of dormant seeds of *Trifolium* species which have been carried out, show that they have a low sensitivity to the physiological effects of radiations. Tascher (1929) estimated that the 50 per cent. survival dose for *T. hybridum* was 85 kr, and that for *T. pratense* 50 kr, while Bruns (1954) reported the action of X-rays on *T. pratense* in the first and second generations, and showed that at about 60 kr the first generation survival is 50 per cent. of controls. Gustafsson (1944) found that the germination of *T. repens* was not affected by X-ray doses of up to 30 kr. The only published study with *T. subterraneum* appears in a C.S.I.R.O. (1951) report in which it was stated that the effect of 30 kr on dormant seeds was slight.

The present investigation on subterranean clover was designed to measure the survival in the first (X_1) generation, and the frequency and types of mutation in the second (X_2) generation.

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Experimental

Air dry (9-10 per cent. moisture) scarified, commercial, Dwalganup, subterranean clover seed, with a germination capacity of 98-100 per cent. on filter pads, was screened to retain seed of 0.16 to 0.21 cm in diameter. Poor seeds were removed, and the remainder X-rayed, using deep therapy equipment operated at 220 KVP in 1954, and 250 KVP in 1956; with no added filtration; HVL 0.15 mm Cu in both years. The dose rates varied between 785 and 1454 r per minute. Four X_1 generation survival trials were made, in which the X-ray dose, the interval between irradiation and planting, and the method of establishing seedlings were varied.

Trial 1. In 1954, two replications of 50 seeds for each of eight dose levels (range 9.9-76.6 kr), as well as unirradiated controls, were planted in randomised blocks four to five weeks after irradiation. The seedlings were established in a glasshouse, and transplanted after six weeks to field rows.

Trial 2. At the same time, an identical trial was made, but with field establishment of seed, in space planted rows.

Trial 3. In 1956, seeds stored under laboratory conditions for 29 months after irradiation at the same levels as in Trial 1 and 2 were planted. 120 seeds at each dose level were established under glasshouse conditions.

Trial 4. In 1956, the survival of plants given an extended series of doses (range 60-120 kr) was measured. Four replications of 100 seeds at each dose level were sown in a randomised block arrangement, at eleven to twelve days after irradiation, under sheltered conditions.

Survival and emergence were estimated in these trials each week for six weeks. The survivors of Trials 1 and 2 were harvested as single whole plants.

Seeds from all plants surviving Trials 1 and 2 were used for an X_2 generation in 1955, a maximum of 30 seeds from each X_1 plant being sown in spaced rows in the field. During the whole growing period mutant types were recorded in the following classes—chlorophyll aberrants, marked morphological variants, and sterile plants.

Results and Discussion

X_1 generation The X_1 generation survival is recorded in Tables 1 and 2. Due to both poor seed and field conditions, the emergence and survival in 1954 were less than in 1956, but very similar trends were obtained in both trials. As with other legumes (Gustafsson 1944, Bruns 1954, Spencer and Cabinallas 1956), the irradiation slowed but did not reduce emergence. This slight effect is in marked contrast to that obtained with cereals, and is probably due to the presence of the epigeal cotyledons and to the pre-formation of first true leaves in these legume seeds.

Deaths due to the irradiation occurred at all stages of growth, especially in the harsher environment of Trial 2. However, under the better conditions of Trial 1, 83 per cent. of all deaths occurred in the first eight weeks, and, except for occasional bifurcation of leaf and petiole meristems, normal growth appeared to be resumed at about this age. Chlorotic mottling, distortion of leaves and petioles, and retardation of growth, similar to that described by Bruns (1954) and Davis and Hammons (1956), occurred in the younger seedlings, the amount being directly related to dose level, with little effect at or below 20 kr. Both the final survival values for 1954, and the survival at eight weeks in 1956 suggest that the 50 per cent. survival dose lies at 60 to 70 kr, when the seedlings are sheltered, and at a rather lower level when established under field conditions. Some variation in this 50 per cent. survival dose can be expected from variations in season, seed size and moisture content (Gustafsson 1944) and strain differences (Smith 1942).

The slow growth of heavily irradiated seedlings in the first few weeks, and the early flowering characteristic of the Dwalganup strain, resulted in these plants being very small at full bloom, leading to the marked reduction of seed set at doses of over 30 kr (Table 1). It is anticipated that planting in late summer to lengthen the vegetative phase would overcome the problem of obtaining sufficient seeds for X_2 families from plants given irradiations of over 50 kr.

The emergence and survival values of freshly treated seed and seed stored for 29 months

TABLE 1

X_1 Generation Survival Trials, 1954 Irradiation

Dose kr	TRIAL 1 Glasshouse establishment, 1954				TRIAL 2 Field establishment, 1954			TRIAL 3 Stored seed, glasshouse establishment, 1956 (1954 irradiation, stored 29 months)	
	Total* emergence %	Survivors at 8 weeks %	Plants setting seed %	Av. no. seeds per plant setting seed	Survivors* at 6 weeks %	Plants setting seed %	Av. no. seeds per plant setting seed	Total** emergence %	Survival at 6 weeks %
Control	74	61	54	100	94	47	45	75	68
9.9	70	62	59	80	76	38	43	68	59
19.8	78	70	62	92	84	36	36	76	61
29.6	76	58	50	73	92	39	27	62	50
39.6	65	48	41	48	50	18	23	69	49
50.5	76	46	38	32	38	12	19	73	32
57.0	72	39	30	31	62	19	12	68	48
67.0	72	41	28	26	60	17	11	51	22
76.6	68	38	22	12	46	5	8	62	3
	$\chi^2 = 2.078$; 8 d.f. for independence to dose	$\chi^2 = 20.92$; 8 d.f. for independence to dose			$\chi^2 = 61.4$; 8 d.f. for independence to dose			Total $\chi^2 = 14.90$; 7 d.f. for conformity with 1954 results.	

*100 seeds sown at each dose level. **120 seeds sown at each dose level.

after irradiation (Table 1) are similar. The only values which have significant deviations between the two sowings occur at the six weeks survival of the 67.0 kr and 76.6 kr doses, which are both close to the 50 per cent survival dose. In these cases, storage reduces survival approximately to that of seed given an extra 20 kr and planted immediately after irradiation. Such a slight effect may be contrasted with the strongly lethal effects of storage found by Tascher (1929), and Gustafsson (1944) in other crops.

X_2 generation. The main results are illustrated in Tables 3 and 4. The small size of most of the X_2 families was due to the reduced numbers and the poor quality of the seeds from heavily irradiated plants, and to poor growing conditions.

In view of the high incidence of chlorophyll aberrant mutants in commercial samples of subterranean clover (Symon 1954) the occurrence of two such mutants in the control group is not surprising. Such spontaneous mutations could inflate the observed mutation rates of the irradiated families. However, the restriction of observations to a few classes leads to a considerable under-estimation of mutation rates. The chlorophyll mutants are useful as a test class in this species, for in this trial 86 per cent. were visible at the 3-trifoil seedling stage, compared with 16 per cent. of other mutants. The scoring of morphological mutants gives some indication of the range and viability of potentially useful mutations, though it may lead to the inclusion of some temporary changes (Gelin 1954).

The ratio of normal to mutant plants in mutant X_2 families is higher than that expected (3:1) for simple recessive mutants in a closely self-pollinated species. Using the sib method

TABLE 2

X_1 Generation Survival, Trial 4, 1956

Dose kr	Emergence* at 1 week %	Total** emergence (at 3 weeks) %	Survival at 8 weeks %
Control	87.2	97.4	94.6
60	73.3	96.6	58.9
70	71.7	94.1	50.5
80	54.9	94.0	31.5
90	51.2	93.3	13.6
100	66.6	95.5	2.9
110	48.2	96.1	0.5
120	54.2	94.1	0.3

*Dose effect highly significant ($p<0.01$), from analysis of variance of transformed percentages.

**Dose effect not significant.

of analysis (Mather 1951) to correct the observed ratio in the small families used, the overall ratio is estimated at 6.45 : 1, and significantly different ($p < 0.01$) from the 3:1 value. This large deviation suggests that it is due not to selection against mutant genes at an early stage, but, as has been found in studies of other X-rayed plants—e.g., by Bruns (1954) and Kaukis and Reitz (1955)—to the mutant X_1 plants being composed chimerically of normal and heterozygous mutant tissues.

As the mean X_2 family size was less than 7, a large proportion of the mutants was probably not detected. This has been demonstrated by the appearance of four additional mutants in twelve X_3 families which have been grown from mutant X_2 families. An approximate adjustment for this is made in Table 3, where probabilities of observing mutants, as well as corrected mutation rates calculated from these probabilities, are shown for each dose level.

The presence of a number of different mutants in mutant families at the higher dose levels (Table 3) is probably due to two or more independent mutations occurring in one X_1 plant when the mutation rate is high. Such multiple mutation may result in selection against mutants at high dose levels if viable

TABLE 3

Statistics of X_2 Generation Trial

Dose kr	Number of χ^2 families	Mean no. plants per χ^2 family	Observed number of mutations per 100 χ^2 families	Probability of observing a mutation in mutant families*	Corrected number of mutations per 100 χ^2 families**	% mutant families containing 2 or more mutations	% mutants in viability classes: Fertile or viable	Reduced fertility or viability	Fully sterile or lethal
Control	101	8.0	2.0	0.74	2.7	0	—	100	—
9.9	94	7.0	11.7	0.69	17.0	0	36	36	27
19.8	93	7.9	11.8	0.73	16.2	0	45	27	27
29.6	83	7.8	10.8	0.72	15.0	0	33	33	33
39.6	54	6.3	20.4	0.65	31.6	0	36	55	9
50.5	47	5.2	25.5	0.58	44.0	20	38	31	31
57.0	46	4.8	34.8	0.55	63.6	14	25	50	25
67.0	45	4.6	44.4	0.54	83.0	25	25	40	35
76.0	20	3.6	25.0	0.45	55.6	25	40	40	20
Totals	583						31	41	28

*assuming a 6.45:1 segregation in all mutant families, and all families to be of mean size within each dose level.

**obtained from columns 4 and 5.

TABLE 4

Classification of mutations from X_2 generation trial

Class of Mutation		No. in Class	Percentage of all Mutants	Percentage of mutations in viability classes		
				Fertile or Viable	Reduced Fertility or Viability	Fully Sterile or Lethal
Chlorophyll Aberrants	viridis	15				
	albo-viridis	8				
	xantha	4	42	32	22	46
	mottled or sectored	10				
	dark green	2				
Chlorophyll Aberrants with other minor changes	viridis, plus large burrs	1				
	viridis, and anthocyanins reduced	1				
Morphological Aberrants						
Slight	leaf alterations	9				
	increased pubescence	4	21	70	30	—
	short internodes	4				
	floral alterations	2				
	leaf crescent alterations with reduced anthocyanins	1				
Drastic	dwarfs	12				
	small plants	15	34	9	67	24
	teratological changes	6				
Semi-sterile		3	3	—	100	—

mutants are linked with other lethal gene or chromosomal changes. However, the regressions of both the crude mutation rates and corrected mutation rates on dose level do not deviate from linearity, although, due to the marked variation, the fiducial limits are wide —5 per cent. limits for the crude rates are ± 17.6 per cent. Also, the present data do not indicate any increase in the proportion of sterile mutants as the radiation dose increases (Table 3), though this would be expected if chromosomal aberrations are often associated with gene mutations. The highest yield of mutants per seed irradiated, and per X_2 family raised, occurred, as expected, at the dose nearest to the 50 per cent. survival dose of 67 kr.

Table 4 illustrates the range of mutations which were observed. Although 42 per cent. of all mutants were chlorophyll aberrants, no true albinos were obtained. These results with subterranean clover correspond to those obtained by Tedin and Hagberg (1952) with yellow lupins, and contrast with the cereals, which yield a high proportion of albino mutants (Holm 1954). However, both in the

general trend that the mutations with the more drastic phenotypic effect—e.g. dwarfs—were less viable than slight mutations, and in the range of types of morphological mutants, the mutations obtained with subterranean clover are very similar to those obtained with many other irradiated plants. In a subterranean clover breeding programme, the elimination of the deleterious mutants constituting the majority of induced mutants, which would be a time consuming operation by pedigree methods, may be facilitated by growing bulk samples of X_2 and later generations in grazed swards for a number of seasons.

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INDEX

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AUTHORS

Alexander, G. N.
Are there climatic cycles?—Melbourne's rainfall examined 235
Angell, H. R.
The relation of districts and of blue mould in seed beds to loss of tobacco in fields in North Queensland . . . 144
Antcliff, A. J.
Salt status and time of bursting of the sultana 76
Antcliff, A. J.
2,3,4-Trichlorophenoxyacetic acid as a spray to replace cincturing of currants 242
Avent, K. L.
Some apple rootstocks and potassium 154

Barrow, N. J.
A source of error in pot experiments with sulphur 339
Beall, L. B. and Hutton, E. M.
Root-knot nematode resistance in two pasture species of Phaseolus 158
Bell, A. F.
The past decade in agriculture—and the next 279
Brock, R. D.
Mutation plant breeding 39
Brown, A. G. and Greenham, C. G.
The control of mistletoe by trunk injection 308

Chapman, R. E. and Young S. S. Y.
A system for assessing the clean scoured yield of Australian greasy wool 63
Conroy, R. J.
Fusarium wilt of rock melon (*Cucumis melo* L.) in New South Wales 152
Crofts, F. C., McGarity, J. W. and Rayner, Hilary V.
The effect of sod-seeding clovers on the productivity of a paspalum pasture in the Richmond river district of New South Wales 329

Dastane, N. G.
Evaluation of root efficiency in moisture extraction 223
Defries, C. H.
Thoughts on farm management studies 28

Fearn, J. T. and Jefferies, B. C.
Light lambs from overfat ewes 149
Ferguson, A. W. and Keraitis, K.
A simple technique for determining the stability of soil aggregates by wet sieving 248
Forster, H. C.
The role of the Institute—a challenge 103
Frankel, O. H.
The biological system of plant introduction 302
Friend, A. H.
Artificial infestation of oranges with the Queensland fruit fly 77
Frith, J. L.
Germination of *Sporobolus virginicus* 69

Gooding, C. D. and Long, J. L.
Some fluctuations within rabbit populations in Western Australia 334
Greenham, C. G. and Brown, A. G.
The control of mistletoe by trunk injection 308
Groenewegen, H.
A salinity survey of the Mirrool Irrigation Area 323
Gruen, F. H.
Extension work in farm management in New Zealand 209
Grylls, N. E. and Rafferty, W. J.
A useful device for handling active insects 150

Hutchison, K. J.
Changes in the thickness, weight and protein content of the skin of two adult merino ewes 238
Hutton, E. M.
Some effects of induced autopolyploidy in white clover, barrel medic, and Wimmera rye grass 227
Hutton, E. M. and Beall, L. B.
Root-knot nematode resistance in two pasture species of Phaseolus 158
Hutton, J. T. and Northcote, K. H.
The moisture status and salinity of soils of the Flying Fox family at Angaston, S.A. 245

Jackson, E. A.
Soil features in arid regions with particular reference to Australia 196
Jarrett, F. G. and Penny, D. H.
A physical assessment of farm productivity 138
Jefferies, B. C. and Fearn, J. T.
Light lambs from overfat ewes 149

Keraitis, K. and Ferguson, A. W.
A simple technique for determining the stability of soil aggregates by wet sieving 248

Langfield, E. C. B.
Time of harvest in relation to grain-breakage on milling in rice 340
Leeper, G. W.
A note on alleged cooler summers 342
Leeper, G. W.
Changing climates and agriculture 232
Long, J. L. and Gooding, C. D.
Some fluctuations within rabbit populations in Western Australia 334

McGarity, J. W., Crofts, F. C. and Rayner, Hilary V.
The effect of sod-seeding clovers on the productivity of a paspalum pasture in the Richmond river district of New South Wales 329
McIlroy, I. C.
The measurement of natural evaporation 4
Mandryk, M.
Control of blue mould (*Peronospora tabacina*, Adam) in infected tobacco seedlings 319
Martin, D. and Robertson, R. N.
Apple storage in Australia 183
Miles, L. G.
Dry farming patterns in Queensland 190
Millikan, C. R.
Phosphate level in the substrate and different day and night temperatures in relation to the growth of flax 51
Molnar, I
Effect of soil erosion on production in a mixed farming area in Victoria 57

Norman, M. J. T.
Weight responses to tick control and phosphate supplementation in beef cattle at Katherine, N.T. 344
Northcote, K. H. and Hutton, J. T.
The moisture status and salinity of soils of the Flying Fox family at Angaston, S.A. 245

Penny, D. H. and Jarrett, F. G.
A physical assessment of farm productivity 138
Philip, J. R.
The role of mathematics in soil physics 293

Rafferty, W. J. and Grylls, N. E.
A useful device for handling active insects 150
Rayner, Hilary V., Crofts, F. C. and McGarity, J. W.
The effect of sod-seeding clovers on the productivity of a paspalum pasture in the Richmond river district of New South Wales 329
Robertson, R. N. and Martin, D.
Apple storage in Australia 183
Russell, J. S.
Nitrogen fertilizer in Australian agriculture 110

Schindler, C.
Agricultural research libraries 34
Simpfendorfer, K. J.
Control of bracken fern by weedicides 243
Skerman, P. J.
Bullamon lucerne (*Psoralea eriantha* Benth)—a plant worth watching 337
Steindl, D. R. L.
Host range of the sugar cane ratoon stunting virus 238
Sutton, G. L.
The problem of Australian strong wheat 19

Till, M. R.
A method of measuring the evaporation loss from sprinklers 333
Tully, Joan
The building of an extension programme 120

White, N. H.
Host—pathogen relations in plants . 129
Williams, O. B.
The effect of irrigated pasture in the rice rotation on seed populations of *Echinochloa crus-pavonis* 331
Young, S. S. Y. and Chapman, R. E.
A system for assessing the clean scoured yield of Australian greasy wool 63

SUBJECTS

Agriculture
Changing climates and agriculture, by G. W. Leeper 232
Nitrogen fertilizer in Australian agriculture, by J. S. Russell 110
The past decade in agriculture—and the next, by A. F. Bell 279
Animal husbandry
Light lambs from overfat ewes, by B. C. Jefferies and J. T. Fearn 149
Animal nutrition
Changes in the thickness, weight and protein content of the skin of two adult merino ewes, by K. J. Hutchinson 238
Light lambs from overfat ewes, by B. C. Jefferies and J. T. Fearn 149
Weight responses to tick control and phosphate supplementation in beef cattle at Katherine, N.T., by M. J. T. Norman 344
Animal parasites
Weight responses to tick control and phosphate supplementation in beef cattle at Katherine, N.T., by M. J. T. Norman 344
Apples
Apple storage in Australia, by D. Martin and R. N. Robertson 183
Some apple rootstocks and potassium, by K. L. Avent 154
Australian Institute of Agricultural Science
The role of the Institute—a challenge, by H. C. Forster 103
Australian Medal of Agricultural Science
Award to Dr. J. Griffith Davies ... 175
Bacteria
Host—pathogen relations in plants, by N. H. White 129
Blue mould
Control of blue mould (*Peronospora tabacina*, Adam) in infected tobacco seedlings, by M. Mandryk 319
The relation of districts and of blue mould in seed beds to loss of tobacco in fields in North Queensland, by H. R. Angell 144
Book reviews 27, 33, 38, 56, 62, 75 226, 249, 264, 269, 291, 318, 322, 328
Bracken
Control of bracken fern by weedicides, by K. J. Simpfendorfer 243
Branch notes 98, 177, 274, 376
Cattle
Weight responses to tick control and phosphate supplementation in beef cattle at Katherine, N.T., by M. J. T. Norman 344
Citrus fruits
Artificial infestation of oranges with the Queensland fruit fly, by A. H. Friend 77
Climate
Are there climatic cycles?—Melbourne's rainfall examined, by G. N. Alexander 235
Changing climates and agriculture, by G. W. Leeper 232
A note on alleged cooler summers, by G. W. Leeper 342
Soil features in arid regions with particular reference to Australia, by E. A. Jackson 196
Clover
The effect of sod-seeding clovers on the productivity of a paspalum pasture in the Richmond river district of New South Wales, by F. C. Crofts, J. W. McGarity and Hilary V. Rayner . 329
Crops
Dry farming patterns in Queensland, by L. G. Miles 190

Nitrogen fertilizer in Australian agriculture, by J. S. Russell 110

Economics
Effect of soil erosion on production in a mixed farming area in Victoria, by I. Molnar 57
A physical assessment of farm productivity, by D. H. Penny and F. G. Jarrett 138

Education
The Institute's submission to the Committee of Enquiry on Australian Universities 214
Submission by the Queensland branch of the Institute to the Committee of Enquiry on Australian Universities 220

Entomology
Articial infestation of oranges with the Queensland fruit fly, by A. H. Friend 77
A useful device for handling active insects, by N. E. Grylls and W. J. Rafferty 150

Evaporation
The measurement of natural evaporation by I. C. McIlroy 4
A method of measuring the evaporation loss from sprinklers, by M. R. Till 333

Extension
The building of an extension programme, by Joan Tully 120
Extension work in farm management in New Zealand, by F. H. Gruen 209

Farm management
Dry farming patterns in Queensland, by L. G. Miles 190
Extension work in farm management in New Zealand, by F. H. Gruen 209
Thoughts on farm management studies, by C. H. Defries . . 28

Farm Production
A physical assessment of farm productivity, by D. H. Penny and F. G. Jarrett 138

Federal President, 1957 . . 93

Fertilizers
Nitrogen fertilizer in Australian agriculture, by J. S. Russell 110
Some apple rootstocks and potassium, by K. L. Avent 154

Flax
Phosphate level in the substrate and different day and night temperatures in relation to the growth of flax, by C. R. Millikan 51

Forestry
Control of bracken fern by weedicides, by K. J. Simpfendorfer 243
The control of mistletoe by trunk injection, by C. G. Greenham and A. G. Brown 308

Fruit—Diseases and pests
Artificial infestation of oranges with the Queensland fruit fly, by A. H. Friend 77
Fusarium wilt of rock melon (*Cucumis melo* L) in New South Wales, by R. J. Conroy 152

Fungi
Control of blue mould (*Peronospora tabacina*, Adam) in infected tobacco seedlings, by M. Mandryk 319
Fusarium wilt of rock melon (*Cucumis melo* L) in New South Wales, by R. J. Conroy 152
Host—pathogen relations in plants, by N. H. White 129
The relation of districts and of blue mould in seed beds to loss of tobacco in fields in North Queensland, by H. R. Angell 144

Genetics
Mutation plant breeding, by R. D. Brock 39
Some effects of induced autopolyploidy in white clover, barrel medic, and Wimmera rye grass, by E. M. Hutton 227

Institute
The Institute—1953-1956 3
The Institute's submission to the Committee of Enquiry on Australian Universities 214
The role of the Institute—a challenge, by H. C. Forster 103
Submission by the Queensland branch of the Institute to the Committee of Enquiry on Australian Universities 220

Institute Affairs
Australian Medal of Agricultural Science—Awarded to Dr. J. Griffith Davies 175
Branch notes 98, 177, 274, 376
Federal President, 1957 93
Personal notes 94, 175, 271, 373
Irrigation
The effect of irrigated pasture in the rice rotation on seed populations of *Echinochloa crus-pavonis*, by O. B. Williams 331
A method of measuring the evaporation loss from sprinklers, by M. R. Till 333
A salinity survey of the Mirrool Irrigation Area, by H. Groenewegen 323

Letters to the Editor 128, 251, 349
Libraries
Agricultural research libraries, by C. Schindler 34
Lucerne
Bullamon lucerne (*Psoralea eriantha* Benth)—a plant worth watching, by P. J. Skerman 337

Marketing
The problem of Australian strong wheat, by G. L. Sutton 19
Mathematics
The role of mathematics in soil physics, by J. R. Philip 293
Measurement
The measurement of natural evaporation, by I. C. McIlroy 4
A method of measuring the evaporation loss from sprinklers, by M. R. Till 333
Mistletoe
The control of mistletoe by trunk injection, by C. G. Greenham and A. G. Brown 308

Nematodes
Host-pathogen relations in plants, by N. H. White 129
Root-knot nematode resistance in two pasture species of Phaseolus, by L. B. Beall and E. M. Hutton 158
News items 89, 169, 265, 363

Nitrogen
Nitrogen fertilizer in Australian agriculture, by J. S. Russell 110

Pastures
The effect of irrigated pasture in the rice rotation on seed populations of *Echinochloa crus-pavonis*, by O. B. Williams 331
The effect of sod-seeding clovers on the productivity of a paspalum pasture in the Richmond river district of New South Wales, by F. C. Crofts, J. W. McGarity and Hilary V. Rayner 329
Root-knot nematode resistance in two pasture species of Phaseolus, by L. B. Beall and E. M. Hutton 158
Some effects of induced autopolyploidy in white clover, barrel medic, and Wimmera rye grass, by E. M. Hutton 227
Personal notes 94, 175, 271, 273
Phosphorus
Phosphate level in the substrate and different day and night temperatures in relation to the growth of flax, by C. R. Millikan 51
Plant breeding
Mutation plant breeding, by R. D. Brock 39
Plant introduction
The biological system of plant introduction, by O. H. Frankel 302
Bullamon lucerne (*Psoralea eriantha* Benth)—a plant worth watching, by P. J. Skerman 337
Plant nutrition
A source of error in pot experiments with sulphur, by N. J. Barrow 339
Plant pathology
Control of blue mould (*Peronospora tabacina*, Adam) in infected tobacco seedlings, by M. Mandryk 319
Fusarium wilt of rock melon (*Cucumis melo* L.) in New South Wales, by R. J. Conroy 152
Host-pathogen relations in plants, by N. H. White 129
Host range of the sugar cane ratoon stunting virus, by D. R. L. Steindl 238
Root-knot nematode resistance in two pasture species of Phaseolus, by L. B. Beall and E. M. Hutton 158

Plant physiology
Evaluation of root efficiency in moisture extraction, by N. G. Dastane 223
Germination of *Sporobolus virginicus*, by J. L. Frith 69
Phosphate level in the substrate and different day and night temperatures in relation to the growth of flax, by C. R. Millikan 51
Potassium
Some apple rootstocks and potassium, by K. L. Avent 154

Queensland
Dry farming patterns in Queensland, by L. G. Miles 190
Submission by the Queensland branch of the Institute to the Committee of Enquiry on Australian Universities 220

Rabbits
Some fluctuations within rabbit populations in Western Australia, by C. D. Gooding and J. L. Long 334
Rainfall
Are there climatic cycles?—Melbourne's rainfall examined, by G. N. Alexander 235
Changing climates and agriculture, by G. W. Leeper 232
Research
Agricultural research libraries, by C. Schindler 34
The past decade in agriculture—and the next, by A. F. Bell 279
Rice
The effect of irrigated pasture in the rice rotation on seed populations of *Echinochloa crus-pavonis*, by O. B. Williams 331
Time of harvest in relation to grain-breakage on milling in rice, by E. C. B. Langfield 340

Salt
The moisture status and salinity of soils of the Flying Fox family at Angaston, S.A., by J. T. Hutton and K. H. Northcote 245
A salinity survey of the Mirrool Irrigation Area, by H. Groenwegen 323
Salt status and time of bursting of the sultana, by A. J. Antcliff 76

Sheep
Changes in the thickness, weight and protein content of the skin of two adult merino ewes, by K. J. Hutchinson 238
Light lambs from overfat ewes, by B. C. Jefferies and J. T. Fearn 149

Soil conservation and erosion
Dry farming patterns in Queensland, by L. G. Miles 190
Effect of soil erosion on production in a mixed farming area in Victoria, by I. Molnar 57

Soil moisture
Dry farming patterns in Queensland, by L. G. Miles 190
Evaluation of root efficiency in moisture extraction, by N. G. Dastane 223
The moisture status and salinity of soils of the Flying Fox family at Angaston, S.A., by J. T. Hutton and K. H. Northcote 245
The role of mathematics in soil physics, by J. R. Philip 293
A salinity survey of the Mirrool Irrigation Area, by H. Groenwegen 323

Soil Physics
The role of mathematics in soil physics, by J. R. Philip 293

Soils
The moisture status and salinity of soils of the Flying Fox family at Angaston, S.A., by J. T. Hutton and K. H. Northcote 245
A simple technique for determining the stability of soil aggregates by wet sieving, by K. Keraitis and A. W. Ferguson 248
Soil features in arid regions with particular reference to Australia, by E. A. Jackson 196

Storage
Apple storage in Australia, by R. N. Robertson and D. Martin 183

Sugar
Host range of the sugar cane ratoon stunting virus, by D. R. L. Steindl 238

Sulphur
A source of error in pot experiments with sulphur, by N. J. Barrow 339

Talks 82, 163, 255, 353
Temperature
A note on alleged cooler summers, by G. W. Leeper 342
Phosphate level in the substrate and different day and night temperatures in relation to the growth of flax, by C. R. Millikan ... 51
Theses
List of theses on which higher degrees were awarded in the faculties of Agriculture of Australian Universities 1950-1956 159
Summaries of theses 346
Tobacco
Control of blue mould (*Peronospora tabacina*, Adam) in infected tobacco seedlings, by M. Mandryk 319
The relation of districts and of blue mould in seed beds to loss of tobacco in fields in North Queensland, by H. R. Angell 144

Universities
The Institute's submission to the Committee of Enquiry on Australian Universities 214
Submission by the Queensland branch of the Institute to the Committee of Enquiry on Australian Universities 220

Vines
Salt status and time of bursting of the sultana, by A. J. Antcliff 76
2,3,4-Trichlorophenoxyacetic acid as a spray to replace cincturing of currants, by A. J. Antcliff 242
Viruses
Host-pathogen relations in plants, by N. H. White 129
Host range of the sugar cane ratoon stunting virus, by D. R. L. Steindl 238

Weeds
Control of bracken fern by weedicides, by K. J. Simpfendorfer 243
The control of mistletoe by trunk injection, by C. G. Greenham and A. G. Brown 308
The effect of irrigated pasture in the rice rotation on seed populations of *Echinochloa crus-pavonis*, by O. B. Williams 331
Wheat
The problem of Australian strong wheat, by G. L. Sutton 19
Wool
A system for assessing the clean scoured yield of Australian greasy wool, by S. S. Y. Young and R. E. Chapman 63

Competition between Wheat and Three-cornered Jack

H. S. HAWKINS and J. N. BLACK

A study was made of the relationships between yield of wheat, infestation by Emex australis Steinh. (three-cornered jack), and level of applied nitrogen in a field of low nitrogen status at Roseworthy Agricultural College, South Australia. Weeds were removed on four occasions during the growing season and dressings of 0, ½ *and* 4 *cwt per acre of sulphate of ammonia were applied at seeding.*

Weed infested crops gave a greater response to nitrogen than weed free crops, indicating competition for nitrogen. It was found that yield was increased both by removing weeds and by increasing nitrogen, and that these treatments operated through the resultant variation in the number of ear bearing tillers per plant.

Even at high levels of application, when nitrogen was apparently no longer a limiting factor, the yield of the weed-free crop was substantially greater than that of the weed-infested crop. This indicates that some factor additional to nitrogen was being competed for and it is suggested that competition for soil moisture at the end of the season may have been responsible for this reduction in yield.

It has long been appreciated that the presence of weeds lowers the yield of cereal crops through competition for various factors of the environment, chiefly moisture, nutrients and light. In the wheat belt of South Australia, where declining yields have been ascribed to diminishing soil nitrogen reserves (Cornish 1949), the effects of weed infestation are likely to be associated with the amount of nitrogen available to the wheat crop. Some 25 years ago substantial increases in the yields of stubble sown cereal crops following the application of inorganic nitrogen were demonstrated in South Australia (Richardson and Fricke 1931; Richardson and Gurney 1933), and in a recent review Russell (1957) has again drawn attention to the possible role of nitrogenous fertilizers in cereal growing in Australia.

In an attempt to elucidate the effects of infestations of the annual weed three-cornered jack (spiny emex or double gee: *Emex australis,* Steinh.) it was decided to examine the relationships between time of weed removal, level of applied nitrogen, and reduction in wheat yield. *Emex australis,* which is widely distributed throughout the cereal growing areas of South Australia (H. E. Orchard, private communication), is a vigorous annual with smooth, fleshy stems radially disposed. Normally prostrate, the plant will assume an erect habit in tall dense vegetation, as in a cereal crop, and the possibility that at certain stages in the growth cycle the weed may shade the cereal, as well as vice versa, cannot be discounted.

H. S. HAWKINS, B.Ag.Sc., was a research student in the Department of Agronomy, Waite Agricultural Research Institute, University of Adelaide, when this investigation was made.

J. N. BLACK, M.A., D.Phil., is Senior Agronomist at the Waite Agricultural Research Institute, University of Adelaide.

Methods

An experiment was carried out at Roseworthy Agricultural College in 1956 on a field where a heavy infestation of Emex was anticipated. From its previous cropping history the field was known to be of low available nitrogen status, having grown wheat for grain in 1954 and oats for silage in 1955. Plot size was 9 drill rows—about 8 links—by 25 links, permitting a central sample area of 5 x 20 links. Dirk wheat was sown at 75 lbs per acre on June 1, with an accompanying dressing of 2 cwt per acre of super-phosphate.

Nitrogen was applied to $\frac{2}{3}$ of the plots to give 3 levels of nitrogen—nil, ½ and 4 cwt/acre of sulphate of ammonia. These treatments will be referred to as N_0, $N_{\frac{1}{2}}$ and N_4 respectively.

Emex plants were removed, by severing at ground level, on 4 occasions.
T_1—clean weeded throughout.
T_2—weeds removed on September 11.
T_3— „ „ „ October 11.
T_4— „ „ „ November 8.

The design of the experiment was therefore:—

Levels of nitrogen(3) x Times of Weed removal(4) x Replication (randomized blocks)(5) = 60 plots.

Records of incident light intensity and of the amount of light reaching ground level in the plots were obtained with a Weston illumination meter on September 11, October 11, and November 8, in two blocks only.

The wheat was harvested on December 18. It was cut at ground level, bagged, taken to the laboratory, air dried and weighed. A 200 g subsample was taken from the material from each plot. From the subsample the number of heads, and the number of grains per head were determined. A second 200 g subsample was taken for a nitrogen determination by the Kjeldahl method. The remaining material harvested from the plots was threshed, and the grain cleaned and weighed. Total straw and grain yields were obtained by summing the weights of the subsamples and the remaining materials.

Results

The germination of Emex plants on the plots was disappointing, probably a result of heavy autumn rains and the necessity for a cultivation prior to seeding to ensure wheat establishment. As a result the distribution of the Emex plants over the plots was not uniform. The numbers of Emex plants per plot are given in Table 1, and although there is an indication that additional nitrogen resulted in greater initial establishment, this was not statistically significant.

TABLE 1

Number of Emex plants per plot (plot area = 1/1000 acre).

Number of Jacks per Plot Recovered at	Level of Nitrogen			
	N_0	$N_{\frac{1}{2}}$	N_4	Mean.
September 11	37	61	80	59
October 11	56	61	51	56
November 8	44	47	49	47

The data of Table 1 also indicate that at the higher nitrogen levels there is a decline in the number of Emex plants, probably due to increasing competition for light from the crop when stimulated by the addition of nitrogen.

The yields of straw and grain for all treatments are given in Table 2. The effects of both time of weed removal and additional nitrogen are highly significant ($P \leqslant .001$) but their interaction is not. It is apparent that yield is increased by approximately the same amount either by reducing weed competition or by applying nitrogen. This is shown by the fact that at N_4 the total straw and grain yield of the weed-infested plot is similar to that of the weed-free plot at N_0.

The final yield of a wheat crop is dependent on the way in which certain morphological characters of the individual plants respond to changes in the microclimate which occur as the crop grows. This microclimate is markedly altered by the presence of weeds, and it was hoped that by a study of these yield components (Engledow and Ramiah 1930) the paths by which the weeds reduced the cereal

TABLE 2

Yield of straw and grain, lb/acre.

Time of Weed Removal	LEVEL OF NITROGEN APPLICATION											
	N_0			$N_{\frac{1}{2}}$			N_4			Mean.		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
Clean Weeded Throughout	4299	2204	6503	4938	2557	7495	5600	2910	8510	4938	2557	7495
September 11	3086	1918	5004	3615	2006	5621	5357	2579	7936	4034	2160	6194
October 11	3020	1764	4784	3219	1830	5049	4387	2227	6614	3549	1940	5489
November 8	2601	1257	3858	2932	1521	4453	4541	1918	6459	3351	1565	4916
Mean	3251	1786	5037	3676	1978	5654	4971	2408	7380	3968	2055	6023

Minimum Significant Differences	P = .05			P = .01			P = .001		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
Times of weed removal	497	249	792	662	332	1056	789	435	1386
Levels of nitrogen	430	216	682	573	288	924	682	376	1210
Treatment combinations	860	431	1386	1146	574	1848	1365	754	2200

yield could be determined. These components are:—

Ear-bearing Tillers per Plant. It is clear from Table 3 that increasing nitrogen application and earlier time of weed removal were each highly significant ($P \leqslant .001$) in increasing the number of ear-bearing tillers per plant.

At the early time of weed removal, and in the absence of added nitrogen, there was a marked reduction in the number of ear-bearing tillers compared to the plots which were clean-weeded throughout; at $N_{\frac{1}{2}}$ there was a small reduction, but at N_4 no reduction occurred. As time of weed removal was delayed, this reduction became more marked and occurred at all levels of nitrogen application.

Grains per Ear. Although the mean number of grains per ear tended to increase with additional nitrogen and earlier weed removal, this was not statistically significant, and variations in this component had little or no effect on total yield.

Weight per Grain. Statistical analysis of the 1,000 grain weight showed that whereas the increase in nitrogen application from $N_{\frac{1}{2}}$ to N_4 had a highly significant effect ($P \leqslant .001$) in decreasing weight per grain, time of weed removal was not significant. This result was unexpected as, in general, the two treatments had similar effects on other plant characters.

To obtain a measure of the extent to which the treatments affect the yield components, and the extent to which the latter contributed to total yield, the percentage changes in yield and yield components were calculated. These indicated that—

1. The number of ear-bearing tillers was the most plastic component, i.e. changes in total yield under different treatments were brought about largely by variations in this character,
2. Although not statistically significant there was a trend towards greater reductions in grain yield with later time of weed removal at N_0 as compared with N_4, and
3. The effect of nitrogen was most pronounced in the presence of weeds, there being about a 60% increase in the grain yield and in

TABLE 3

Yield Component Data.

Weeds removed at	Level of Nitrogen.											
	N_0			$N_{\frac{1}{2}}$			N_4			Mean.		
	Ear-Bearing Tillers/Plant	Number of Grains/Ear	1000 Grain Wt. (gms.)	Ear-Bearing Tillers/Plant	Number of Grains/Ear	1000 Grain Wt. (gms.)	Ear-Bearing Tillers/Plant	Number of Grains/Ear	1000 Grain Wt. (gms.)	Ear-Bearing Tillers/Plant	Number of Grains/Ear	1000 Grain Wt. (gms.)
Clean weeded throughout.	4.1	25.1	49.5	4.7	25.8	49.2	5.3	27.6	46.3	4.7	26.2	48.4
September 11	3.0	26.5	49.4	4.2	25.3	48.1	5.3	26.0	44.0	4.2	25.9	47.2
October 11	2.7	25.0	49.5	3.6	25.6	49.9	4.3	27.3	44.6	3.5	26.0	48.0
November 8	2.3	24.4	47.9	3.3	25.9	48.2	3.7	24.8	45.2	3.1	25.0	47.1
Mean	3.0	25.3	49.1	4.0	25.7	48.9	4.7	26.4	45.0	3.9	25.8	47.7
Minimum Significant Differences	P = .05			P = .01			P = .001					
Times of weed removal	0.77	2.51	1.48	1.02	3.35	1.98	1.34	4.39	2.60			
Levels of nitrogen	0.67	2.17	1.28	0.89	2.90	1.71	1.17	3.80	2.25			
Treatment combinations	1.31	4.33	2.57	1.75	5.79	3.43	2.30	7.59	4.50			

the number of ears per plant between N_0 and N_4 in the weed-infested plots and only a 30% increase in the weed-free plots.

The addition of nitrogen increased the percentage of total nitrogen in the wheat grain from 1.97 (N_0) and 1.95 ($N_{\frac{1}{2}}$) to 2.20 (N_4), an increase significant at $P \leqslant .001$, but there was no significant effect of time of weed removal, although there was an indication that at N_4 grain nitrogen tended to fall with later weed removal.

Although time did not permit sufficient light measurements being taken to justify statistical analysis, certain trends were unmistakable. In Figure 1 the light intensity at ground level is shown as a percentage of the light intensity above the crop for N_0 and N_4 in the T_1 and T_4 plots—that is, in weed-free and weed-infested plots. It is clear that the addition of nitrogen, by increasing the amount of vegetative growth, has considerably reduced light intensity at ground level, and that the presence of weeds markedly affects light transmission at N_0 throughout the growth of the crop. At N_4 the wheat is better able to compete successfully for light during the early growth stages and the effects of weeds on light at ground level are not apparent till the final occasion. The data for the intermediate treatments fall between the extreme values illustrated.

Discussion

The general similarity between an earlier time of weed removal and an increasing application of nitrogen is a noteworthy feature of the results. The effect of nitrogen in increasing the yield of wheat was not unexpected, and although the data on time of weed removal are not strictly comparable with, they are supported by the similar work of Blackman and Templeman (1938) and Holmes and Tahir (1956). It has been shown that there was a greater percentage response of the weed-infested than the weed-free crop to added

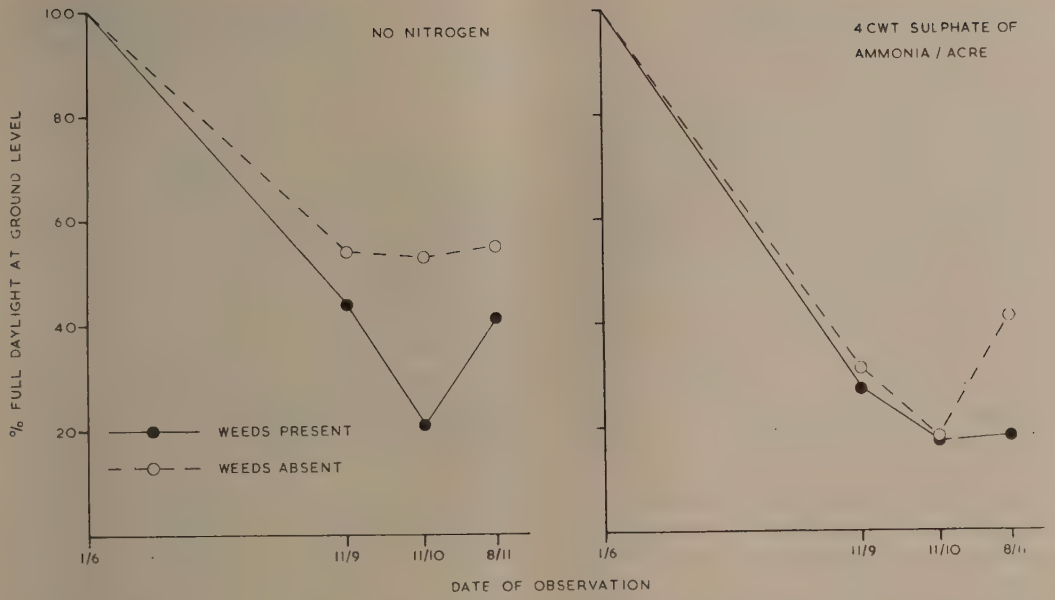

Figure 1—The effect of nitrogen application and weed infestation on the percentage daylight reaching ground level.

nitrogen, an effect which was considered by Blackman and Templeman to be sufficient evidence of competition for nitrogen, and there can be no doubt that such competition did occur in the present experiment. However, by plotting the yield of grain against nitrogen level it should be possible to determine whether nitrogen is still limiting at N_4. Presentation of the results in this way (Figure 2) indicates clearly that between $N_{\frac{1}{2}}$ and N_4, nitrogen ceases to be a limiting factor. On the other hand it is clear that even when nitrogen is non-limiting there is still a depression in grain yield when weeds are permitted to remain in the crop. If competition for nitrogen were the sole factor involved, grain yields at N_4 would be expected to be similar in weed-infested and weed-free crops. Some additional factor to nitrogen must therefore be operative in the competitive relationships of wheat and weed in this experiment, and although there is no direct evidence, the following possibilities may be put forward:—

Competition for Soil Moisture. The rainfall for the months April to September was 16.9 in., evenly distributed, as compared with the 74 year average of 11.5 in., and it is extremely unlikely that competition for moisture took place in this period. The October rainfall of 1.6 in. was average, but November rainfall was only 0.7 in. as compared with an average of 1.1 in. Thus towards harvest time there may

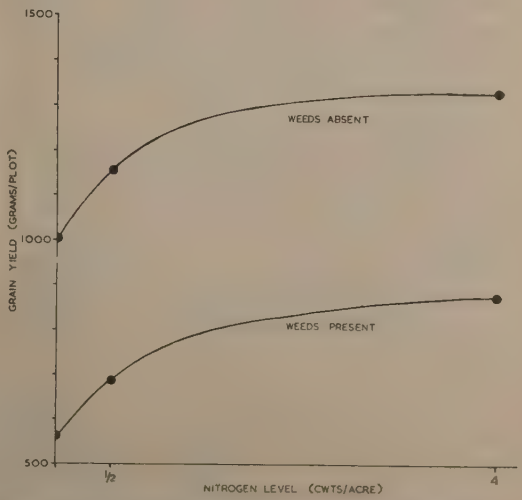

Figure 2—The effect of level of applied nitrogen on the yield of wheat in weed-free and weed-infested plots.

have been some competition between weed and crop for available moisture.

Competition for Light at early stages of growth. By the beginning of September it was evident that the addition of nitrogen had stimulated establishment and seedling growth of the Emex plants and this may have been sufficient to cause them to compete with the wheat plants for light, either reducing the rate of growth or affecting the development of one or more of the yield components to such an extent that final grain yields were lowered. The Emex plants were observed to assume an erect habit in the dense wheat crops and may well have shaded the wheat, although the latter eventually grew taller and ultimately suppressed them. However, the reduction in grain yield at N_4 between wheat weeded in October and weeded in November suggests that this explanation is unlikely to be correct.

The results of this experiment indicate the extent to which even a moderate weed infestation can reduce cereal yields (in this instance by 39 per cent) and also show that the longer these weeds are permitted to remain in the crop, the greater is the reduction.

The yield of grain on a weed-free plot was equivalent to 36.7 bushels per acre where no nitrogen was added, 42.6 bushels per acre with half cwt of sulphate of ammonia and 48.5 bushels per acre with four cwt. In weed-infested plots, grain yields were 20.9, 25.3 and 31.9 bushels per acre respectively.

At current prices of sulphate of ammonia, an application of a half cwt per acre costs about 17/6, and one of four cwt about £7. Therefore on a weed-free field, with wheat at 13/- a bushel, the financial gain from a half cwt application would be about £2/19/- per acre, and from a four cwt application, about 13/- per acre. On a weed infested field, where no steps are taken to remove the weeds, the value of these two levels of nitrogen application would be about £2 and 3/- per acre respectively.

Alternatively, it may be seen that the presence of weeds at N_0, $N_{\frac{1}{2}}$ and N_4 led to financial losses of £10/15/-, £11/4/- and £10/16/- per acre respectively, when the grain yields are compared with the yields in the plots in which weeds had been removed, even though weed densities in this experiment were not high.

Acknowledgments

The authors wish to acknowledge the assistance of the Principal of Roseworthy College and of Mr. N. R. McKeown in making available facilities for the experimental work. Thanks are also due to Professor C. M. Donald for advice at all stages of the work, and in particular to Imperial Chemical Industries Ltd. for a financial contribution towards the costs of this investigation.

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Technical Notes

A Salt Meter for Field Use

Field determinations of soil reaction have been found to be very useful in soil survey work and there is a need for similar measurements of the salt content of soils. A simple prototype conductivity meter has been made for this purpose and is intended to give the same kind of semi-quantitative values as the field pH kit (Raupach 1950). With accessories this prototype weighs a little less than 2½ pounds.

This saltmeter is based on the ordinary ohm-meter principle. A square-wave AC generator supplies a maximum current which gives a full scale reading on a milliammeter. When an unknown resistance—in this case the resistance of the soil suspension or the water—is included in the meter circuit the deflection of the meter is reduced accordingly. The meter scale therefore ranges from infinite to zero resistance or in terms of salt content from zero to infinite concentration. By choosing a suitable electrode size it is possible to spread the useful range of salt concentrations over most of the meter scale.

This saltmeter can be adapted to various techniques but the 1 : 5 soil to water suspension technique is used as a standard method because it is simple and rapid. This meter is not intended to give results of laboratory accuracy and in fact this is not practicable in a simple field method. In view of the way in which the soil suspensions are prepared and the inexactness of the relation between conductivity and salt concentration the prototype meter has been calibrated with an open scale appropriate to the accuracy of the meter.

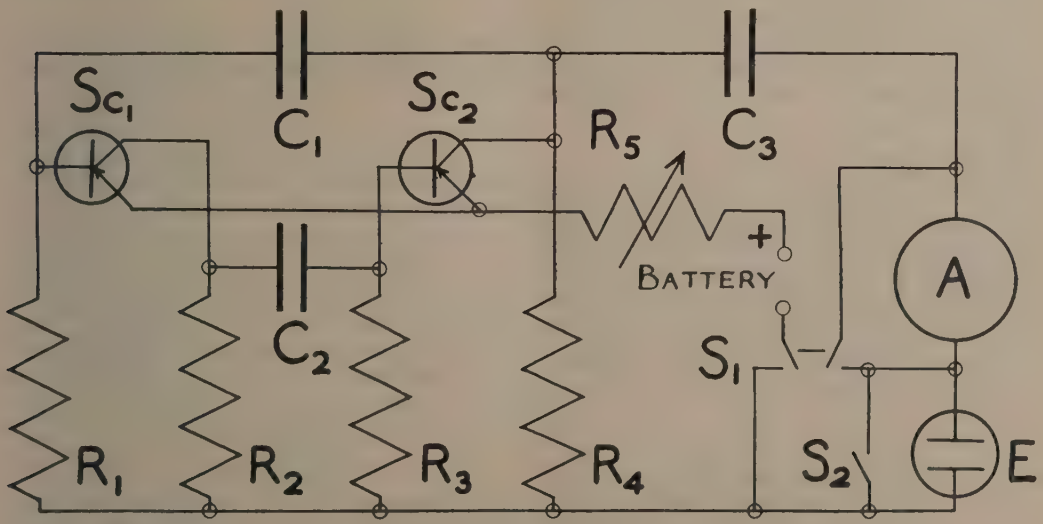

Figure 1—The electrical circuit of the saltmeter

COMPONENTS

R_1—67,000 ohms
R_2, R_4—4,700 ohms
R_3—56,000 ohms
R_5—500 ohms (variable)
C_1 C_2—0.04 μF
C_3—5 to 8 μF (miniature)
E—Electrodes
SC_1, SC_2—transistors OC71 or OC66
A—AC meter 0 to 500 μA
S_1—SPDT switch ON switches on battery OFF shorts meter (optional)
S_2—shorts electrodes for calibration
Battery—2 x 1.5 volt dry cells (pen size)

DESCRIPTION

The Electrical Circuit

The circuit is based on a transistor oscillator (Anon. 1956) which delivers a square-wave alternating current of about ½ milliampere at 0.7 volts and 300 cps. The characteristics of the output vary somewhat with the actual values of the condensers and resistances in the circuit. The principal additions to the basic circuit are a variable resistance which is used to adjust the input voltage to give a standard output (calibration) and a filter condenser to remove any DC component from the output. The oscillator does not work when it is connected directly into the meter circuit without this condenser. The circuit is shown in Figure 1.

The Scale

The scale for the prototype is shown in figure 2. The concentration scale, which is intended for use with waters, is based on measurements made at 20°C on potassium chloride solutions. It would be possible to include scales for other temperatures but this is hardly justifiable for the purposes of this meter. The salt content scale is based on a calibration curve prepared for soils of known salt contents using the field technique described below.

The Electrodes

The pair of electrodes is a simple immersion type made from two short pieces of thick silver wire soldered to flexible wire and fixed into a suitable plastic block with casting resin (Araldite). The external dimensions of the electrodes are: diameter of wires 1.625 mm, centres 4 mm apart and protruding about 1 mm from the plastic. The first electrode pair was adjusted to suitable dimensions for the oscillator output and the desired concentration range; replicate electrodes were made larger than necessary and then adjusted by filing off the silver wires to give the same scale readings in KCl solutions as the original pair. Silver is satisfactory for the electrodes except that it is rather soft.

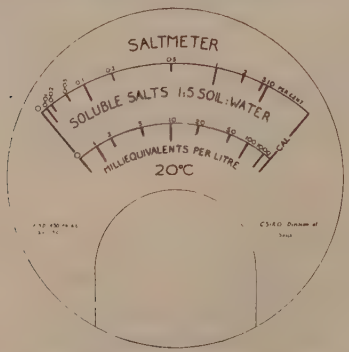

Figure 2—The saltmeter scale.

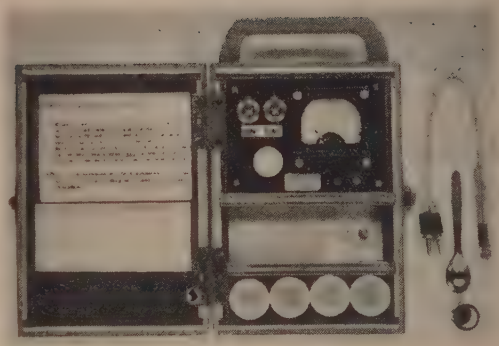

Figure 3—The prototype saltmeter. The electrodes, spoon and measuring cylinder are carried in the centre compartment of the box.

Other Equipment

Some other pieces of equipment are needed. These are a small stainless-steel or nickel spoon (¼ teaspoon size: the one shown holds 0.9 ± 0.1 g of air dry soil), a small plastic measuring cylinder to hold water equal to five times the weight of soil in the spoon (made if necessary from plastic tube and sheet), some plastic pill bottles for preparing the suspension, and a supply of distilled water. The complete instrument is shown in Figure 3. The electrodes, measuring cylinder, plastic bottle and spoon are shown beside the meter. These accessories are carried in the box; the water supply is carried separately.

FIELD USE

The saltmeter is very easy to use: it is ready immediately it is switched on, and the calibration and reading take only a few seconds.

Method for soils

1. Put one level spoonful of soil and one measure of water in a bottle and shake for about one minute.
2. Switch on the meter (S_1) and short the electrodes (S_2 CAL position). Adjust R_5 so

that the meter reads full scale (at CAL).

3. Switch the electrodes into the circuit (S_2 to READ position), immerse the electrodes in the suspension and read the salt content on the meter scale.

NOTE. False readings will be obtained if the electrodes rest on the bottom of the bottle or in the soil sediment.

Method for waters

1. Switch on the meter (S_1) and short electrodes (S_2 to CAL position). Adjust R_5 so that the meter reads full scale (at CAL).

2. Switch the electrodes into the circuit (S_2 to READ position), immerse the electrodes in the water, and read the salt concentration in milli-equivalents per litre on the meter scale.

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The Colour of Wool

There are several causes of colour effects in greasy wool, namely—

1. Pigmentation.
2. Adventitious dust.
3. The 'lanaurin' or 'Golden Coloration' in 'suint'—the water soluble fraction of the wool yolk—a colour which readily scours out.
4. 'Canary' stain, which may develop in fleece conditions of high humidity and temperature, particularly with a highly coloured suint and will not scour out.
5. Pigments produced by chromogenic bacteria in warm, wet fleeces.
6. Discolorations due to dipping sheep in aqueous copper sulphate liquors or the application of drenches such as phenothiazine.

Matters concerning colour effects have been studied in this laboratory at various times and have not been reported. Some of these results are gathered here.

A. *The Fading Fastness to Arc Radiation and Ultra Violet Light and to Heat, of Bacterial and Canary Stains and Golden Coloration.*

Samples of Violet, Green and Red bacterial stains and of Canary Stain and Golden Coloration were submitted to (a) radiation chiefly visible light from the arc light of the Atlas Fadeometer, to (b) an Hanovia Ultra Violet Lamp at two feet; and to (c) a drying atmosphere of 103-5°C at 1 per cent relative humidity (approximately). In (a) the official Society of Dyers and Colourists light fastness standards (1-3) were used for comparison purposes. The complete scale ranges from 1-8 the units being in geometric progression with a factor of 2. The results are shown in Table I.

Seddon (1937) has adequately described other reactions of bacterial stains.

B. *The Assessment of Off-White Colours of Greasy or Scoured Wool.*

The first problem is the preparation of a uniform colour surface from an unevenly coloured staple. Immersion of wool in liquids of similar refractive index to the wool gave both a colour and a turbidity, the latter preventing absorptiometric measurement or comparison of the colour. Alternatively, it was found that wool staples cut into 2-3 mm lengths and pressed lightly into absorptiometer glass cells, gave a fairly uniform colour. The advice of C.S.I.R.O. Division of Physics indicated that the tendency in U.S.A. and on the Continent was to resort to the spectrophotometer and not the colorimeter for accurate colour measurement. Of the two possibilities, the luminous reflectance and the chromaticity, co-ordinates of the latter were proved adequately reproducible using a suitable spectrophotometer.

TABLE 1

Effect of various types of light on different stains on wool.

Exposure to Visible Light Atlas Fadeometer	Violet	Green	Red	Canary	Golden
Fastness 1	Faded to near white	Faded to Green-Brown	Faded to White	Little change	Duller
Fastness 2	White	Brown	White	Duller	Reddish hue
Fastness 3	White	Brown	White	Same as 2	Duller brown hue
Ultra Violet Light					
24 hrs. at 2ft.	Slow fading to paler colour	Tendency to browning	Slow fading	No change	Hue lighter
Drying atmosphere					
103°-5°C 1½ hours	No effect	—	—	No effect	Very slight change

C. *Visual discrimination of Off-Whites.*

The discrimination of 'Off-Whites' by the normal human eye is known to be surprisingly good, particularly if empirical standards of "plaster of paris" including known percentages of suitable pigments are used for comparison. It has been noted that the inclusion of water soluble coloured chemical salts has led to non-uniformity in the colour during the setting of the plaster and these are not recommended.

D. *The Estimation of dust content by the degree of penetration of dust along the staple.*

The mineral matter in the distal staple varies in colour with the soil over which the sheep has been grazing. As Lipson and Black (1945) have noted, the dirt content is the most variable factor in yield determinations of Australian wool. However they have recorded a fairly constant specific gravity for the mineral matter — (1.94-2.39). Cannon and Hyland (unpublished data 1954) working in the laboratory investigated the relationship of length of penetration along the staple to the total quantity of dust and found that they were not significantly correlated.

E. *The effect of* 0.2 *per cent. aqueous copper sulphate on the dyeing properties of the wool with copper sensitive dyes.*

The wool from 8 one-year merino wethers which had been dipped in 0.2 per cent aqueous copper sulphate was shorn three months after dipping. The fleeces were random sampled to give five samples from each fleece, each sample of 30 gms weight. After soap-soda scouring, the wool was ashed slowly in a porcelain dish over a flame and the copper

TABLE 2

Copper Content percentage on dry wool basis

	Fleece	Belly	No. of Estimations
Undipped	0.0000	0.0000	3
Dipped (greasy)	0.0260	0.0110	12
Scoured	0.0108	0.0070	12
Scoured after water rinse	0.0095	0.0066	5

content determined by the method of Callan and Henderson (1929); being reported in Table 2.

Loose wool dyed with the copper sensitive dyes Orange II and Solochrome Dark Blue B S showed slight off-shade effects.

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Staple Length—Quality Number Relationships in Australian Wool

Johnson, *et al.* (1951) have shown that the unstretched staple length of greasy wool more nearly represents the mean fibre length of worsted top, than does the stretched staple length. Lang and Chaudhri (1948) have noted that staple length in Merino wool indicated mean fibre length. It has been suggested (Anon 1954, 1953) that commercial length classes in six principal market grades, which may be related to British quality numbers (Anon 1956). Munz (1950) and 'Jason' (1951) have cited general quality number-staple length categories for Australian wool. There is however little empirical information available concerning the actual staple lengths in the various qualities.

There may be various lengths associated with the same quality, namely, good length or shafty (warp); good average length (warp and half-warp); medium length (half-warp) and short or French combing in Merino wools; and long, medium and short categories in Crossbreds. Attention was concentrated on the warp (Merino) or long (Crossbred) samples and measurements of unstretched staple length made as follows—

A. Ten staples were randomly withdrawn from ½ lb. samples representing Central Wool Committee 1917-8 types 1-180; 263-355; selected by the official appraisers in

TABLE 1

Quality Number—Staple Length (cms) of Australian Wool

Quality Number	Munz	1917-8	1952-3
	cms	cms	cms
Merino 80's	7.0	6.80 (50)	7.15 (200)
Merino 74's-70's	7.6	7.05 (310)	8.30 (1500)
Merino 66's-64's	8.9	7.65 (640)	9.00 (1400)
Merino 60's	8.9	7.87 (410)	9.60 (1400)
Comeback 64-60's	10.1	8.29 (310)	
Crossbred 58's	10.1	8.70 (250)	11.40 (800)
Crossbred 56's	⩾12.7	9.65 (130)	12.80 (900)
Crossbred 50's	⩾15.2	11.00 (130)	13.90 (1000)
Crossbred 46's	⩾15.2	12.79 (120)	15.00 (1000)
Crossbred 44's	⩾15.2	15.44 (80)	16.30 (600
Crossbred 40's	⩾20.4	15.21 (140)	15.5 (700)
Crossbred 36's	⩾20.4	16.75 (160)	20.25 (200)
Crossbred 32's	⩾20.4	21.95 (100)	24.90 (100)

Numbers of single staple samples, or readings, given in brackets

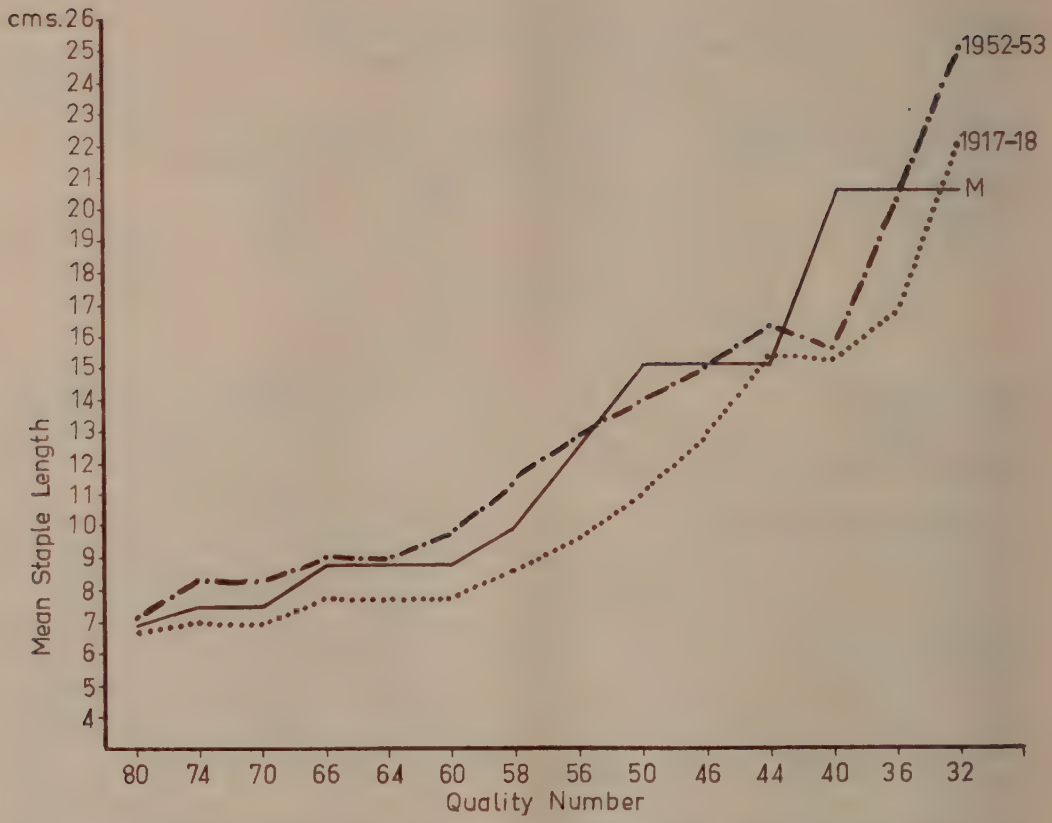

Figure 1—Quality Number—mean Staple Length curves for Munz, 1917-8, and 1952-3 values.

1917-18 and at present in the keeping of this laboratory. Of these only the warp length samples have been reported. The relaxed staple length has been measured and the means of the groups of 10 determined.

B. Several hundred staples have been measured from quality groups prepared by the Woolclassing Department of the Gordon Institute of Technology and representing Geelong market samples of the clip 1952-3.

Results have been compared with Munz values.

The tendency of the 1917-8 values to be lower in several qualities than either the Munz categories or the 1952-3 values is interesting. This is made obvious by Plate 1, which also illustrates the slight concave—upward shape of the curve relating staple length and quality number. No reason can be advanced for the deviation of 44's from the main curve in 1917-8 or of 40's from the 1952-3 group, except that the qualities tend to be in short supply and samples with staple crimp, length and fineness, correct, may be more difficult to obtain.

Bulks of definite quality have been examined to ascertain the distribution of staple length. The coefficients of variation of staple length appeared to be restricted to less than 5 per cent. in most cases, with one exception in the 80's class, where 7 per cent. was noted.

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Weed Control in Pasture Species Trials

The evaluation of different strains of pasture species presents many problems but perhaps the most difficult one is weed control. While the capacity to compete with weeds is an important attribute in a pasture plant, it is usually desirable to make an initial assessment of strains on the basis of their relative production under pure sward conditions.

Cultivation seldom gives more than partial weed control and must be followed, either by hand weeding, or by botanical analysis of the cut material. Moreover, planting must be delayed for at least a week or more after the opening rain of the season. The weeding of hand sown rows grown for single plant selection or seed increase, is both expensive and unsatisfactory, as, even after the competition has been removed, growth is usually retarded and many plants may be lost by accident.

For some years DNOC has been used by the W.A. Department of Agriculture to control double-gees (*Emex australis*) and capeweed (*Cryptostemma calendula*) in cereal breeding rows. This herbicide cannot be used for the control of weeds in such species as subclover, but the effectiveness of two pre-emergence herbicides, Vapam (Sodium methyl-dithio-carbamate (anhydrous)) and Allyl alcohol was tested during 1957. Both products gave satisfactory results at approximately the same cost. Their use involves pre-wetting of the soil, to soften the weed seeds already present, treatment with the herbicide and, in the case of Vapam, sealing the treated area with water.

Weed control for the single plant selection rows was obtained by pre-wetting a strip eight inches wide to a depth of six inches, from a 44 gallon drum mounted on a garden tractor. A hose from the drum to the water main was dragged back and forth as the machine travelled and thus the water in the drum was constantly replenished. This enabled the machine to be operated without stopping. However when the herbicide was being applied, using the same equipment, it was

Figure 1—This shows the effectiveness of the control achieved.

Figure 2—Applying C.M.U. and 2,4-D herbicides to control the growth between the rows. The plants in the rows were shielded with masonite strips.

necessary to stop every three chains to recharge the drum. In some of the rows an alternative method was used, the herbicide was applied by hand through a six inch shower rose connected by a hose to the supply tank.

The control obtained is shown in Fig. 1. Later, in order that the area between the rows could be treated with CMU and 2-4D Amine herbicides the strip adjacent to the rows was hoed by hand. This was done before Fig. 2 was taken. Although the inter-row application of these later sprays was effective, some damage to the sub-clover occurred. This appeared to be due to the 2-4D washing from the treated area on to the clover.

A pre-emergence herbicide was used, also, to control weed growth prior to sowing two sward trials. The whole block was treated using tynes to pre-wet and to apply the herbicide 3-4 inches below the surface. An interval of four weeks occurred before planting and no deleterious effects were observed.

The weeds controlled during a summer trial included crabgrass (*Digitaria sanguinalis*) and pigweed (*Portulaca oleracea*) and in the autumn they included grasses such as wild oats (*Avena fatua*), double-gee (*Emex australis*) including dormant seeds, capeweed (*Cryptostemma calendula*), wild radish (*Raphanus raphanistrum*), variegated thistle (*Silybum marianum*), and stagger weed (*Stachys arvensis* L.), Ungerminated sub-clover seed appeared to survive the treatment.

Apart from the unpleasant odour of these herbicides and the need to exercise care in handling them, the principal disadvantage was the setting of the clay soils after the repeated wetting and puddling associated with the treatments. The results indicate, however, that the use of pre-emergence herbicides can greatly reduce the cost and difficulties of row trials with herbaceous plants.

The cost of the pre-emergence herbicides was about six shillings per chain for the row strips and £26 per square chain for the swards. Full details of the equipment and mode of application are available from the authors.

Acknowledgment

The authors wish to express their thanks to Mr. G. R. W. Meadly, Officer-in-Charge, Weeds and Seeds Branch, Department of Agriculture, Perth, for his assistance with the project.

A. J. MILLINGTON
*G. A. PEARCE

Institute of Agriculture
University of Western Australia
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Received for publication October 14, 1957.

Thesis Summary

The Soils of the Sorell-Carlton-Copping Area of County Pembroke, Tasmania with Special Reference to Soils Formed on Basalt

A detailed field and laboratory study of soils formed on basalt, in the Sorell-Carlton-Copping area of south-east Tasmania is reported, while other soils are described in a general way and their major boundaries defined by reconnaissance survey. The area is hilly, and rainfall varies from 22 inches in the west to 35 inches in the east, with an accompanying vegetation range from savannah woodland to wet sclerophyll forest.

The basalt soils, varying from black earths and prairie soils to krasnozems, are discussed in order as they occur in five topo-sequences. Many of the differences between soils of a single sequence have been attributed to the influence of topography and drainage. Differences between freely drained members of different sequences have been accounted for by climatic and associated vegetation influences. Variation within the parent basalt is considered to account for minor soil differences only.

Evidence is presented which strongly suggests that wind-blown dust has made a contribution to the parent materials of many of the basalt soils and consequently must also contribute to that of other nearby soils.

The mapping unit used in the reconnaissance survey was the great soil group and combinations thereof, following in the main the definitions of Stephens (1953), although relationships with the groups of other workers have been discussed. Krasnozems, podzols, ground-water podzols, grey-brown podzolics, black earths and prairie soils and various soils with poorly differentiated profiles have been recognised. Climatic and parent material differences are shown to explain the basic pattern of these soils.

An important contrast from the agricultural point of view between soils from basalt and from dolerite, including similar black soils from both rocks, is that the former soils have a much higher phosphorus content than the latter, and this is directly attributable to the difference in phosphorus content of the rocks.

Reference

Stephens, C. G. (1953) "A Manual of Australian Soils" (C.S.I.R.O. Melbourne).

J. LOVEDAY

Awarded the degree of M.Ag.Sc. by the University of Adelaide in 1956

The Genetic and Physiological Basis of Flowering in Subterranean Clover *(Trifolium subterraneum L.)*.

The inheritance of flowering time in subterranean clover, using a number of strains and hybrids among them, was investigated on autumn sown material at Canberra.

Heterosis and dominance were not found, and genetic variation was polygenic. An F_1 diallel analysis and F_2 two-way analysis showed that approximately 90 per cent. of the total variance was attributable to additive genetic effects.

An estimate of the repeatability of strain performance over two seasons showed that

small but significant strain-year interactions were occurring. Strain repeatability, as measured by intra-class correlation, was 86 per cent.

A breeding test involving F_2 selections and their progeny gave a mean parent-offspring regression of 0.86 over the six crosses studied, which is well in accord with expectations of breeding behaviour based on the above analyses.

The results are discussed in relation to other studies on flowering time, especially with reference to the problem of interpreting results based on the threshold expression of a character dependent on the value of a continuously variable factor.

Publication: The Inheritance of Flowering time in *Trifolium subterraneum* L., C. I. Davern, J. W. Peak, and F. H. W. Morley *Aust. Jour. Ag. Res.* **8**, pp. 121-134, 1957.

C. I. DAVERN

Awarded the degree of M.Sc.Agr. by the University of Sydney in 1956

The Influence of Defoliation on the Growth of Subterranean Clover *(Trifolium subterraneum L.)*.

Replicated swards of 'Bacchus Marsh' subterranean clover sown at four densities (1, 4, 14, and 50 plants per square link) were defoliated once by removing 50 per cent. of the tops. Time of defoliation varied—viz. 9.5, 13.5, and 17.5 weeks after sowing. A fourth (control) group was not defoliated. All plots were harvested 21.5 weeks after sowing. The effects of the treatments on dry matter yield and leaf area were studied.

At varying times after defoliation the content of non structural carbohydrates in the roots and tops of high density and low density swards was determined. Respiration rates were measured and losses of carbohydrate due to respiration were estimated in an attempt to assess the role of stored carbohydrates in regrowth.

Both dry matter production and leaf production were found to be dependent upon the leaf area index (LA1), or ratio of leaf area to ground covered, at the time of defoliation. Reduction of high LA1's (swards of high density or later in the season) led to increased leaf production and dry matter yields. Leaf production was the most affected, and defoliation of swards with LA1 greater than 5 led to an increased rate of leaf area increase, increased leaf production (up to 69 per cent. increase), and higher protein yields (up to 32 per cent. increase).

Decreases in non structural carbohydrates of both roots and tops were induced by defoliation. Respiratory losses could account for more than the loss of carbohydrate found in the roots. It appears unlikely that the 'carbohydrate reserves' of the roots contribute at all to regrowth following defoliation. Translocation of carbohydrates from the tops to roots, together with respiratory losses, are considered to be responsible for carbohydrate losses in the tops remaining after defoliation. Sward development is discussed in terms of a carbon balance between photosynthesis and respiration.

J. L. DAVIDSON

Awarded the degree of M.Ag.Sc. by the University of Adelaide in 1956

Letters

Animal Husbandry

Dear Sir,

In his recent letter to the Journal, Professor McMillan has, somewhat to my consternation, charged me with making "grossly misleading statements" about the curriculum in the Faculty of Agriculture at Sydney University. The only mention of Sydney in my note was in the statement that "Specialization in animal husbandry in existing courses as is now planned in the Faculty of Agriculture at Sydney, or post-graduate training, although both playing valuable roles, cannot fully meet the need." The need referred to that "for a course specifically orientated about the fields of knowledge involved in livestock production, with opportunity for specialization again within that field". This is of course an expression of opinion, with which Professor McMillan is entitled to disagree as vehemently as he wishes; but it does not I think allow a charge of being "grossly misleading". By first making this charge, and then listing the accomplishments of the Faculty of Agriculture Professor McMillan tends rather to suggest that he interpreted my remarks as belittling the Faculty. Such an intention could not have been further from my mind. My personal and academic regard for the Faculty of Agriculture of the University of Sydney is of the highest order.

My other statement, to which Professor McMillan may have taken exception, that agricultural science courses, in general, are primarily centred on soils and plants "with largely only orientating reference to livestock" was and is I believe fair comment.

To make my position clear might I restate that it is *my view* (to avoid another charge!) that specialization in "animal husbandry" in agricultural science courses is a valuable development which will contribute towards the range of the types of training available for meeting different requirements and interests. But it is also my view that to produce specialized graduates in the fields conventionally regarded as "agricultural science" on the one hand, and "animal husbandry" on the other, the courses of training should be differently designed from first year. To contend that the one course can with only minor modification provide the basic training necessary for an "agricultural science" graduate or "animal husbandry" graduate is in my view either to minimize the width and depth of training necessary in this day for competence in agricultural science, or to fail to appreciate the width and depth of training necessary in a basic "animal husbandry" course. Such a contention also overlooks the fact that there is an equal need for opportunity for under-graduate specialization within the "animal husbandry" field (such as in nutrition, applied genetics, physiology, poultry science, etc.) as there is within the agricultural science field.

The difficulty in the way of logical discussion and disputation on "animal husbandry" and its teaching is of course that of definition of terms, animal husbandry meaning many things to many people—from preventive medicine to many veterinarians, to anything to do with livestock to many agricultural scientists. It is for this reason that we have eschewed use of the term and have reserved the term "livestock husbandry" to cover the field directly concerned with types and breeds of livestock, livestock products, and management practices and cycles. If there is any similarity between the ideas of Professor McMillan and my own as to what is involved in "animal husbandry", the term must include anatomy, histology, physiology, pathology, livestock diseases, "livestock husbandry" and applied genetics—which seems rather to stretch the dictionary definition of "husbandry" somewhat beyond its elastic limits!

Yours, etc.,

G. L. McCLYMONT
Professor of Rural Science
University of New England
Armidale

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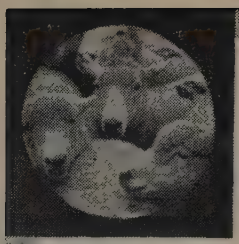

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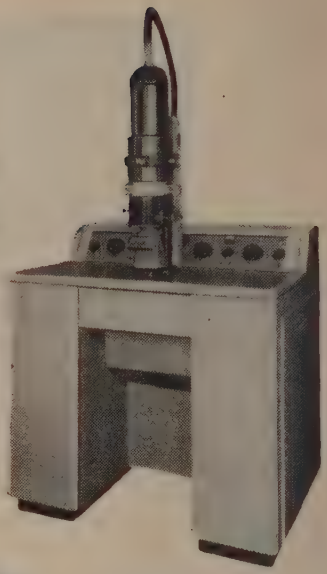

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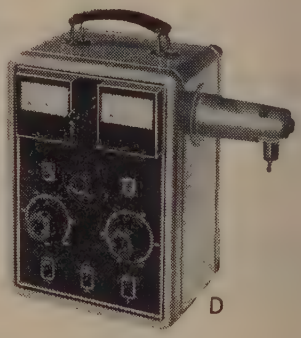

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DROUGHT MITIGATION

On October 31, 1957, the N.S.W. Branch and the "Men of the Land" Society held a joint Symposium on Drought Mitigation. Five of the six talks are summarized here. It is hoped to publish the sixth—Dr. M. C. Franklin's "Droughts can be Beaten"—in full in a later issue.

The History of Drought in Australia

Professor R. D. Watt, Emeritus Professor of Agriculture, University of Sydney

Although Australia is blessed with a climate of moderate temperatures, it is nevertheless the driest of continents and is subject to droughts at irregular intervals. Approximately one third of our area is so arid that it is practically useless, another third is capable of carrying only a very sparse population of sheep and cattle, whilst the remaining third with a satisfactory average rainfall is subject to dry spells and droughts at fairly frequent, but very irregular intervals. The exception to this irregularity is the annual occurrence of summer droughts in the south and winter droughts in the north.

The first drought encountered by the early settlers was that of 1798-9 and, from accounts, many followed but the intensity or scope of these cannot be accurately assessed until the period 1860-70 when a sufficient number of meteorological stations were established to evaluate droughts in terms of actual rainfall. Mr. J. C. Foley, recently of the Meteorological Bureau, Melbourne, has attempted a classification of the drought years up to this period. Droughts occurred 1798-99; 1809-11; 1813-15; 1824; 1826-29; 1837-39; 1845-47; 1849-50; 1857-59.

The following is the classification (ref. J. C. Foley) of drought years for the period when rainfall records have been available:—

Major Droughts Widespread and severe	Less severe or less extensive droughts
1863-66	
	1870-71
	1876-78
1880-86	
1888	
1895-1903 (1902 drought)	
	1904-10
1911-1916 (1914 drought)	
1918-1920 (1919 drought)	
	1922-23
	1926-29
	1935-38
1939-45	
	1946-49
	1951-52

The most disastrous drought in the history of Australia was the 1902 (1895-1903) drought, the effects of which were intensified by the advent of the rabbit. Sheep numbers were halved, cattle populations reduced by 30 per cent. The 1914 drought was perhaps comparable with this in the southern states.

The 1918-20 drought caused sheep losses of 12.4 million in the Commonwealth, including 9 million in N.S.W. Fodder was imported from America.

Then followed a relatively good period of 20 years before the 1939-45 drought which affected chiefly the wheat belt and pastoral areas. Wheat yields in N.S.W. fell to 6 bushels per acre in 1944 and 3.5 in 1946. Sheep population in the Commonwealth dropped from 125 million in 1942 to less than 100 million in the next 4 years.

The past 10 years have been generally favourable.

Droughts and dry spells of unpredictable intensity and duration are part of the environment with which we have to contend and our continued success and prosperity depends very largely on the success of our efforts in combating them.

What are Our Fodder Reserves?

A. J. McIntyre. Chief Liaison Officer, Rural Liaison Service, Commonwealth Bank of Australia

Before discussing the size and adequacy of Australia's present stocks of fodder, there is one point I would like to stress most firmly . . . *Drought is a*

Normal Business Risk of Farming. As with any other business risks action can be taken, and should be taken, to insure against it.

The best drought insurance Australia can have is a large reserve of fodder, whether it be hay, silage or grain. In establishing the size of such reserves we should establish some priorities.

First and foremost the aim should be to keep all breeding stock alive. Secondly it is more important to keep young stock alive than aged stock. Other fodder reserves will be dependent on costs.

We might compare the present situation with that of 1943 when we were facing the 1944-47 drought. Overall, it seems that Australia is probably somewhat better placed at the present dry spell than it was when the 1944 drought was around the corner. Stocks of grain, hay and silage are better, pastures are now being stocked more leniently, decimation of the rabbit population might be set down at the equivalent of 20 million sheep, there are one million fewer horses, there is half a million acres more irrigated pasture while improved pastures have increased five-fold.

But the big question is "Has the improvement been good enough".

Unfortunately the answer must be "No".

In the two worst years, 1944-45 and 1945-46, farmers fed their stock a total of 9,500 million food-units and yet 16 million sheep died. To have kept them alive and maintained the progeny would have required 5,000 million more food-units or a total of 14,500 million food-units of supplementary feed would have been necessary to have prevented above-normal deaths in the two drought years, assuming that water supplies were adequate.

Taking into account present stock numbers, grain, hay and silage stocks, next season's crop, etc., and assuming we are facing a two year drought, we have only 10,000 million food-units or about two-thirds of the amount that would have been needed to maintain stock in 1944-45.

The problem is how to ensure that adequate fodder stocks are on hand in the event of drought, despite some graziers' aversion to conservation. One way that I would like to put to you for consideration and discussion is the establishment of a National Fodder Board.

The Board would maintain a reserve of, say, 100 million bushels of wheat over and above normal stock feed requirements, to prevent stock losses in a major drought. This would involve an initial capital cost of over £50 million and an annual charge of £5 million. These costs would have to be borne by those most likely to benefit; this would be difficult to manage. Anyway I leave these thoughts with you.

The Role of Improved Pastures

B. H. Harris, Agricultural Advisory Officer, Australian Fertilizers Ltd.

From practical experience in the field, it is generally agreed that successfully established and correctly managed improved pastures do have a mitigating effect on the repercussions from dry times. Improved pastures are not effective in overcoming the problems of prolonged droughts, but at least by deferring the onset of the critical period they do mitigate the severity of the drought.

Improved pastures mitigate the effects of drought in several ways. Firstly the improved pasture is responsible for the commencement of a soil fertility cycle by which the organic content of the soil is built up, physical condition is improved, moisture retention is improved, a layer of humus collects on the surface reducing exaporation and there is a chemical fertility uplift. This upward trend in the soil fertility cycle allows for a wider range in the selection of pasture species and results in a more rapid regeneration of pastures following drought breaking rain.

Improved pastures on a property with their high nutritive value can help in the utilisation of the less nutritious native pasture, which, if fed alone would be of little value. In addition the parasitic infestation of the stock is controlled more readily with this higher plane of nutrition.

Full utilisation of improved pastures requires that reserves for supplementary stock feeding as well as drought fodder reserves be maintained at all times. Improved pastures provide high value feed which is economical to conserve.

Improved pastures make for more effective pasture utilisation due to the fact that rotational grazing and strip grazing is in many instances carried out.

Landholders practising pasture improvement are generally more alive to the problem of the rabbit which has been responsible in part for the severity of past droughts.

There are two species which we must keep in mind particularly where the mitigation of the severity of dry times is our aim. These are *Lucerne* and *Phalaris,* which are deep rooting and perennial. A combination of Lucerne and Phalaris along with

another annual legume is perhaps one of our best pasture mixtures which we can look to on much of our Western slopes where the problem of climate must always be foremost in our minds.

Gains Analysed

Mr. Harris illustrated these points by quoting examples of successful pasture improvement on three properties in the Central Tablelands, Crookwell and New England areas. He concluded:—

"Landholders whose properties are pasture improved and well managed have felt the impact of the recent dry spell far less than those with unimproved country, and with this in mind, there can be no measure of doubt that improved pastures correctly managed, are playing a very vital role in the mitigation of the severity of dry times".

Stop Wasting Pastures

Mr. W. M. Willoughby, Principal Research Officer, Division of Plant Industry, C.S.I.R.O.

Both on the home and export market the grass crop-converted into animal products—is about four times as valuable as all other agricultural production. And yet it is the crop about which we know least, especially concerning efficiency of utilisation.

A feature of pasture is that it is a variable commodity. Thus it is that the rate of stocking is adjusted on the minimum pasture available and in the good seasons the excess is wasted.

Figures presented showed that if the annual average pasture grown in N.S.W. is 140 million tons, the fluctuations between years would be in the order of 40 to 200 million tons.

Further figures showed that an average flock or herd, as a result of seasonal fluctuations in pasture, receives full dietary demands for three to four months of the year, two-thirds for another four months and only one one-third for the remaining four to five months.

In good years and drought, utilisation of the pasture probably fluctuates between 15 per cent. and 80 per cent.

Natural pasture wastage cannot be readily reduced, in fact it may be a more appropriate procedure for more pasture to be wasted by adopting a relatively low rate of stocking.

Sown pasture wastage is of more immediate concern. Sown pastures respond more closely to climatic changes and the fluctuations between seasons are magnified. If the excess pasturage could be conserved it would amount to an average of one ton of hay or three tons of silage per year for each acre of sown pasture.

The numerous practical difficulties must be solved by the agriculturalist and the engineer.

It has been found that although paddocks may be grazed and fodder conserved also in the one year, in dry years the conservation of the pasture seriously reduces the grazing value of the pasture. This fact modifies the glowing picture so far presented.

There is a need for a more co-ordinated attack on pasture problems.

"I have great faith in the possibilities of efficient and economic methods of considerably reducing the enormous wastage of pasture, and thereby of economically increasing animal production."

Water Conservation

C. C. Corbett. Chairman, Water Conservation and Irrigation Commission.

In opening my talk I would like to adapt as a text that Australia is a land of extremes. This is evident in the behaviour of the great river system of the Murray. This system with 414,253 square miles of catchment includes a quarter of a million square miles in the arid zone; the rainfall over the whole basin averages 16½ inches compared to 26 inches for all the land areas of the world. Only 16 per cent. of the rainfall becomes running water compared to a world average of 37 per cent. The average annual discharge of 5½ million acre feet sounds quite impressive until compared with the Amazon 1,780 million and the Mississippi, 470 million acre feet. In droughts the flow is nil, in the floods of 1956 total discharge was 44 million acre feet. It is important that a balance be struck between these two extremes.

A start has been made with the construction of storage Dams such as Hume on the Murray, Burrinjuck on the Murrumbidgee, Wyangala on the Lachlan and Keepit on the Namoi while storages are to be built at Murrendong on the Macquarie, Menindie on the Darling, Glenbawn on the Hunter.

Storage dams may be accompanied by irrigation areas such as on the Murray and Murrumbidgee

or may lead to greatly increased production by private irrigation under licence, such as the Lachlan Development.

Farm Water Supplies

Technical advice and assistance have been afforded to 9,000 landholders over the past ten years and in most cases these schemes have been implemented with appreciable benefit to themselves and to the State. Supplies have been maintained for stock, irrigation and domestic purposes on a State-wide scale.

Artesian Water

Artesian water flow has now been somewhat more stabilised, equilibrium is expected to be arrived at in 15-20 years. Wastage is high. Development of sub-artesian water supplies continue at a fairly rapid rate, more than 2,000 new bores and wells being drilled each year in N.S.W.

There is a true statement that in primary production there is no substitute for water and that if the whole of the water which flows in our streams were conserved, the total available would not suffice to irrigate more than a small percentage of the land which would be suitable for irrigation in our arid areas. It therefore behoves us as a country which must, for many years at least, depend on primary production, to use all available means to conserve what water we have.

The Cattle Industry in Australia

Mr. Marshal Irving, Chief, Division of Animal Industry, South Australian Department of Agriculture, to the S. Australian Branch.

The Cattle Industry differs from other livestock industries in that it is Australia wide. All other livestock industries are local in comparison to the beef industry. Research must thus think in wide terms. Some programmes have failed because of a narrowness in outlook.

Historical

Cattle came in with the First Fleet but it wasn't until 1820 that better breeds began to arrive. In this early period Australia was fortunate in missing out on many of the major diseases which affect cattle elsewhere.

The early industry grew up on hides and tallow. Boiling down works were scattered throughout the outback. In 1860 the first freezing works was built by Mort in Sydney and in 1883 the first frozen beef shipment was made to the U.K. This resulted in a change of emphasis in production and most of the boiling down works were closed.

The industry suffered two great set-backs in the latter part of the 19th century. In 1872 ticks were introduced in beasts brought in from Timor by the company building the Overland Telegraph from Darwin to Adelaide. The ticks swept through the northern part of Australia and in 1906 penetrated into New South Wales. Up to 80 per cent. of some herds were killed by this pest. The second great setback was the drought of 1902. Over half the beef cattle in Australia perished.

There has been some competition between cattle and sheep for available country. A stable pattern has now been reached and cattle occupy country that sheep cannot graze because of climate or diseases.

Statistics

Meat Total Production	1,220,000 tons
of which beef comprises	750,000 „
Meat Exports	200,000 tons
of which beef comprises	144,000 „

Of the sixteen million cattle in Australia eleven million are beef cattle of which six million are in Queensland. There is a scant quarter million in South Australia. Most of the cattle population is to the north and north east of Australia. Centres of consumption are concentrated in the south and south east which accounts for the great interstate movement of cattle.

This enormous movement is easterly and south easterly and is mainly along an arc extending from the Kimberleys across Northern Territory into Queensland and sweeping across New South Wales into Victoria. It is quite possible for a beast to be born in the Kimberleys and be slaughtered in Melbourne. There is also some movement from the Kimberleys by sea to Perth and from the centre and channel country into South Australia.

Breeds

The Shorthorn is the main breed in the north. It was first there and has stayed there because its temperament is right. Herefords are equal in numbers but are mostly confined to the coastal belt of New South Wales and Queensland. Aberdeen Angus arrived much later than the first two breeds. They have made little impression except in some Highland areas. The Devon breed is frequently forgotten but the influence of this breed on the Shorthorn is very noticeable.

Problems

1. Disease—Three main diseases.

Ticks—Played havoc when first introduced and they are still there. They stretch from Broome across

the north to the New South Wales border and there is one pocket in New South Wales. Greatest economic loss being equal to all other diseases put together.

Pleuro pneumonia—Came in 100 years ago. It is steadily being pushed back. It is mostly in the north and sparsely throughout Queensland. It is not serious in the north—only serious when introduced to the south.

T.B.—Not serious except inland. In fact it is non-existent in coastal beef herds. Inland its presence is related to the existence of wild pigs and is spread by their scavenging on dead carcases.

2. Production and Transport

Labor shortage is one of the most serious problems. This is related to remoteness and lack of transport. Distance adds greatly to costs so much so that the initial cost of say, a ton of wire has little meaning.

3. Marketing

The health of the industry is tied up with exports which are in a very poor state at the moment.

Comparative recent prices at the Smithfield (U.K.) market indicate this.

Argentine chilled hind quarters	....	25-26d./lb.
N.Z. „ „ „	....	24-25 „
Australian „ „ „	....	19-23 „
Argentine frozen hind quarters	....	16-17 „
Australian „ „ „	....	14-15 „

(90 per cent. of our exports)

Australian beef in U.K. is of poor quality. Most of it never gets into shops but is used in institutions, e.g., armed forces, gaols, asylums, etc. Chilling, however, presents numerous problems.

Progress

1. Disease

Some progress has been and is being made.

Progress is being made in eradicating pleuro pneumonia from half a million square miles to the north of South Australia. Next step will mean clearing pleuro pneumonia from an area containing 4,000,000 cattle. This will take twenty years.

Tick. Eradication is extremely difficult and costly. An eradication programme at present in operation in 5,000 square miles of New South Wales is likely to cost two million pounds. Little hope in this method for the vast infested areas of the North.

2. Production and Transport

Good stock routes have been made in the north with nineteen miles between waters. The Birdsville track has also been improved. The standard railway extension to Marree in South Australia has greatly facilitated transport. Also the projected standardisation from Albury to Melbourne will enable cattle to move from Bourke to Melbourne on the one system.

The two most desirable railway extensions are firstly on the branch line from Mt. Isa into the Northern Territory across some very rough country. The second desirable extension is the junction of Cunnamulla in Queensland and Bourke in New South Wales. However, fears of loss of trade by Queensland are likely to prevent this.

Recent development is the use of road trains. These will move along the wartime built road from the Northern Territory to Mt. Isa. It is too early yet to assess their future.

There is much research going on at the present time. No less than 82 different projects by State Departments and C.S.I.R.O. are at present in operation.

Some work in the past has been done on exotic breeds but the temperament of some of these animals mitigates against their use in the broad unfenced areas of Australia at the moment.

3. Marketing

This is the great problem because it is little use producing meat which cannot be sold. Future does not lie in chilled beef. The margin in time is so small that co-ordination can be easily upset by shipping delays, killing difficulties and strikes.

Greatest hope probably lies in flash freezing small parcels—frozen 40°F. for 1-2 hours and then stored at 10°F. Glenroy Air Beef pioneered this method and there is much scope for its introduction elsewhere.

There is more room for expansion in the beef cattle industry than any other livestock industry and a 100 per cent. increase in production is not out of the question in the future.

Black Earths of the Darling Downs

Mr. C. Muir, Student Finalist, Queensland Branch Prize.

An arable soil cropped for 30 years, and a virgin soil, from the black earths of the Darling Downs were compared. Determinations made on the soils were, organic carbon, total nitrogen, carbon-nitrogen ratio and nitrification capacity. Wheat was then grown in the two soils, and it was analysed for protein percentage after eighteen weeks.

The virgin soil was significantly higher, in total nitrogen, nitrification capacity, wheat protein percentage, and total weight of wheat protein than the arable soil. There was no significant difference in organic carbon percentage, carbon-nitrogen ratio, or

plant weight. There appeared to be a good relationship between nitrification capacity and wheat protein percentage.

Water Usage and Soil Fertility

Mr. G. Diatloff, Student Finalist, Queensland Branch Prize.

The water usages of barley plants grown under three different fertility levels of a podsolic soil, were determined. Although nitrogen fertilization increased the total water used, the water usage per unit of dry matter produced was reduced.

Salts, Yield and Ion Uptake in Young Barley

Mr. B. R. Grant, Student Finalist, Queensland Branch Prize.

Two experiments were carried out to investigate the depression which calcium chloride was found to have on young barley plants. A comparison was made between calcium chloride and sodium chloride at concentrations from 25 to 150 milliequivalents per litre; and between calcium chloride and calcium nitrate at concentrations from 25 to 100 milliequivalents per litre.

It was found that both calcium and sodium chloride depressed yield significantly with increasing concentration, but calcium chloride depressed yield more severely at high levels than did sodium chloride. This depression could not be attributed to interference with the plant's water uptake because of increasing concentration of the applied solution, nor could it be explained by accumulation of either calcium or chloride ions singly to toxic levels.

The comparison between calcium chloride and calcium nitrate showed a depression of yield at the 75 to 100 millequivalents levels only, with calcium chloride whilst there is no depression at any level with calcium nitrate.

From the results obtained in the percentage moisture and dry weight it appears unlikely that osmotic effects play any but a very minor role in determining salt damage. Further, it appears that, while calcium is not toxic itself at high levels, it does affect the toxicity of chloride if this is present at high levels. However, it does not act by allowing either greater uptake or translocation of chloride within the plant. Chloride does depress yield by itself at high levels but it is more toxic in the presence of calcium than in the presence of sodium at equivalent levels. No explanation can be offered for this.

News Items

O.I.C. for C.S.I.R.O. Irrigation Research Station, Griffith

Mr. E. R. Hoare, B.Sc., M.I.E.E., has been appointed as Officer-in-Charge of the C.S.I.R.O. Irrigation Research Station, Griffith, N.S.W.

Mr. Hoare comes from the United Kingdom Institute of Agricultural Engineering, Silsoe, Bedfordshire, England. He has been in charge of the Horticultural Engineering Department.

Mr. Hoare graduated in mechanical and electrical engineering at the University of London in 1934. For eleven years he was Research Engineer and Physicist with the U.K. General Post Office. He undertook important assignments for the armed forces during the war including the synchronization of all radar stations on the east coast of Britain, and the design and installation of D-day cross-channel communications.

Mr. Hoare has applied his experience as a radio and electrical engineer to the study of the basic requirements of the growing plant. In this work he and his team of research workers have developed many original and sensitive electronic instruments for assessing such factors as the respiration of plants and their sensitivity to light and heat.

Among the projects successfully developed by the Horticultural Engineering Department under Mr. Hoare's guidance have been: study of the water take-up in plants both in glasshouse and open ground cultivation; cultivation and tractor problems; plant culture under glass with special reference to heat requirements; crop and pest spraying problems; study of light, radiant energy and radio activity in relation to plant growth.

Plastic Dam Linings

Polythene for dam lining has, for some time, been available in strips up to about 7 feet wide which has made it necessary to find a satisfactory method of fabricating the strips into large sheets. Existing heat sealing or sticking methods did not stand up to the need to make the sheet strong and completely waterproof. The supply of large membranes delivered already sealed by a novel and entirely effective method has overcome this difficulty.

Black VisQueen polythene film used in dam lining is only 4 thousandths of an inch thick. It is therefore light and easy to carry. A membrane to cover a storage tank with a capacity of 85,000 gallons (equivalent to 5,000 square yards in surface) weighs 100 lbs. and can easily be carried by a working team of ten men.

After the dam or tank has been lined, and preferably, before it is filled, the dam should be fenced to prevent stock from damaging the membrane. In most cases when the dam is designed for stock drinking, it is necessary to erect a windmill with watertrough.

The cost of polythene membranes is very low compared to all other known ways of protecting dams and tanks from seepage. It works out at approximately 6½d. per square foot. Thus, prices would range from approximately £120 for 500 cubic yards containing 85,000 gallons of water, to approximately £1,000 for 10,000 cubic yards containing 1,700,000 gallons.

The development work on this method of lining dams was carried out by ICIANZ jointly with Plastalon Ltd., a Melbourne plastics company which evolved a new type of machinery to seal VisQueen into large membranes and which supplies the fabricated liners.

Research on Beef Cattle for Northern Australia

The Technical Committee of the National Cattle Breeding Station at 'Belmont' met in Rockhampton late last year to hear reports of the year's work and to plan for the future. The Department of Agriculture and Stock, the Australian Meat Board and C.S.I.R.O. (the operating authority) are represented on the board.

The broad aim of the work at 'Belmont' is to find why some breeds, and some individual animals within breeds are more able than others to thrive in high temperatures, often with scanty feed of low nutritive value. Having found these answers it should be possible to select and breed the types best suited to tropical conditions. The problem has to be tackled from many angles.

Coat type

The Committee heard an account by Mr. H. G. Turner of studies on coat-type in relation to thriftiness.

Field observations had shown that differences in coat within a line of Herefords or Shorthorns are sufficient to cause large differences in heat tolerance which are also closely related to growth rates. In a group of 120 British-breed weaners, the ten per cent. with the shortest coats put on twice as much weight (178 lb) in the ten months after

weaning as did the ten per cent. with the longest coats (88 lb).

Performance of mature cows is also related to coat type. The cows that had the longer coats at mating time gave poorer calving percentages.

In a herd of 160 wet cows calving percentage was 48 per cent. for that half of the herd with the longest coats and 70 per cent for the remainder. Birth weight of calves was also affected. In a herd in which 206 cows calved, half of the herd with the longer coats at mating time dropped calves averaging 4 lb less than calves from the cows with shorter coats.

It is not yet certain that differences in thrift are directly caused by differences in coat. Coat type may be the result rather than the cause. Experiments at the McMaster Field Station show that the type of coat varies with the level of nutrition. But the evidence does suggest that an animal's inherited coat type strongly influences its growth and well-being in a hot environment.

Coat character depends mainly on depth of cover, but the length, density and diameter of the hairs, the angle at which they lie, their curvature and their structure all contribute to the overall effect. Precise definition of coat characters is complex, but very satisfactory comparative judgments of coats can be made by hand and eye.

Coat type is strongly inherited. Selection for sleeker coats should be effective in changing coat type and improving adaptation to hot environments.

Eye Troubles in Herefords

Mr. G. French is taking the opportunity of having some 200 mature Herefords under close observation at Belmont and making a close study of the lesions of the eyes and eye-lids to which the breed is particularly liable, in the tropical regions. Many of these lesions are unimportant in themselves but a proportion develop into cancers.

Pigmentation of the eye-lids reduces the incidence of lesions and cancers. Preliminary observations at Belmont which showed horny "Tags" and eroded skin of the eye-lids, and early cancer-like lesions of the eyeball and third eye-lid to be common in eyes with unpigmented lids and rare when the lids are well pigmented. The Herefords' eyes will be examined periodically to note how the early lesions change and which of them develop into cancers.

It seems that this cause of wastage among Herefords in near tropical regions could be reduced to a negligible level by breeding animals with well-pigmented eye-lids. Selection for this character should be effective as it is strongly inherited.

First Fully Mechanized Cheese Making

Cheddar cheese can now be made in a completely mechanized plant developed by C.S.I.R.O. The new plant cuts out much hard manual labour and reduces costs of cheese manufacture.

The new plant was demonstrated to leading members of the dairy industry by Mr. J. Czulak of the C.S.I.R.O. Dairy Research Section, Highett, Victoria, who was largely responsible for its development. The plant incorporates a high temperature cheese-making process which cuts the cheddaring (or curd-fusing) time from 90 minutes to only 30 minutes.

The new high temperature process produces excellent cheese of the same type as that produced by the time-consuming older methods.

Most important innovation in this speeded up process is the addition to the normal cheese starter of a second starter which is heat and salt resistant. The new plant comes into operation after the curd is formed. Milk is coagulated in the normal cheese vats using the two starters and rennet. Both curd and whey are then pumped into the new plant. The whey is drained off and the curd is compressed between plungers in a cylinder to fuse the grains of curd together.

The block of curd then passes into a second oval cylinder where it is again compressed. During this compression the curd flows in the direction of the long axis of the oval. This flow produces the important longitudinal fibre or chicken-breast structure of well-cheddared curd.

Finally the slab of cheddared curd is automatically ejected, sliced, milled, salted, mixed and hooped.

Capacity of the demonstration curd-fusing machine is 600 pounds of curd per hour. Four units of this size could handle the production of a factory receiving 10,000 to 14,000 gallons of milk per day.

Wool Bureau's Statistical Analysis of 1956-57 Clip

The proportion of fine wools (60's quality and above) in the 1956-7 Australian clip was 76.7 per cent., as compared with 74.5 per cent. in 1955-56. (Statistical Analysis No. 23, by the Wool Statistical Service of the Australian Wool Bureau). The clip was some 12 per cent. larger than the previous one, so the baleage of wool available in the merino quality range showed a substantial increase.

During the season 4,753,630 bales were sold. This was up approximately 600,000 bales on the previous season. There has been a fairly steady rise since 1946-47 when 2.7 million bales were auctioned.

The increase in the percentage of merino quality wools in 1956-57 occurred mainly in South Australia—the increase in Adelaide offerings coming

mainly from pastoral areas, and in Western Australia, where drier seasonal conditions prevailed.

There was little change in the pattern from the Eastern States. The increases in production there being spread fairly well over the range of qualities. For Australia as a whole, although the 1956-57 clip was somewhat finer, it again fitted into the long term trend, which is for the bulk of the clip to concentrate within the 60-64 range.

For the first time over two million bales (42.8 per cent.) were classified as free or nearly free of vegetable fault. The average yield of the clip, estimated at 59.9 per cent., was nearly one per cent. higher than the previous season; and was thus the highest yielding of any post-war clip.

Role of Bees

South Australia has become very bee minded with the visit to the Waite Institute of Prof. J. E. Eckert, professor of entomology and apiculture at the University of California, Davis, USA. Dr. Eckert said that the important part played by bees in agriculture had been increasingly appreciated in America in recent years.

Fruitgrowers had been the first to realise that bees could increase their crops, he said. They found that by bringing in bees and placing the hives in the orchards they would get greatly increased yields. Following the fruitgrowers, commercial seed producers became interested in bees as a means of increasing their seed yields. Testing the effects of bees on clover seed yields, scientists found that yields from sections of fields closed to bees at flowering were very poor.

Since then not only fruit, lucerne and clover seed producers but farmers and vegetable growers had realised the great importance of the honey bees in pollinating their crops.

S.A.-N.T. Cattle Industry Development

Cattle have been able to move freely from Central Australia into S.A. from February 1 without being subject to quarantine for pleuro-pneumonia. This follows the establishment of a protected area of more than 400,000 square miles in Central Australia two years ago and from which the disease has now been eradicated.

To prevent the possibility of cattle from other areas coming in contact with those from the free area, duplicate cattle-handling facilities are being provided at Marree rail transhipment point and at the Adelaide abattoirs. The plan will allow N.T. cattle stations to send their young stores south for fattening and to run larger numbers of breeders.

Sir Edwin Tooth Bequest

One of the major bequests in the will of Brisbane philanthropist Sir Edwin Tooth, who died in May, 1957, provided for the foundation of an Agricultural Research Institute within the Queensland University. The Institute will be known as "The Sir Edwin Marsden Tooth Institute for Agricultural Research". It is understood that the bequest will be in the vicinity of £60,000 and that the income from the bequest will be used for scientific personnel and special equipment.

By a previous benefaction Sir Edwin had provided for glasshouse facilities on two acres of the University Domain at St. Lucia which have been allocated for agricultural and botanical work.

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Sub-Committees in the Victorian Branch

J. P. BRIEN

As the Institute advances into a new stage of its growth, this is a convenient time to review one aspect that has become established on the Institute horizon in the last decade. It is the reputation gained by the Victorian Branch for the manner in which it can initiate, plan and organise its activities.

This reputation is really a practical illustration of the theme expressed by Professor H. C. Forster in his Presidential Address to the twenty-fifth General Meeting in Sydney in March 1957 in which he said that the future of the Institute was tied to members feeling that "it's not what the Institute does for me that matters; it's what I can do for it."

Background to Victorian Branch Sub-committees

Towards the end of the 1940's, successive Branch Committees in Victoria formed a number of sub-committees to help them in their work. Following the success of these sub-committees more were introduced in the intervening years until in 1956, thirteen were operating. In all, 12 per cent. of the total membership of the Branch served on the main committee or associated sub-committees.

This seems an extraordinarily high proportion for a professional organisation of this type but the sub-committee system in the Branch has two distinct advantages.

1. The everyday work of the Branch can be spread among many members.

2. There is a constant infiltration of more new ideas into the Institute circle than would come solely from the main committee.

Types of Sub-committees

Sub-committees operating in 1956 were of three types:—

A. Those providing day to day assistance to the main committee.

B. Those assisting the main committee by putting forward recommendations on specialist subjects.

C. Those assisting the main committee by reviewing constantly certain aspects of agricultural science or the profession and making appropriate recommendations.

Types A and C are continuing sub-committees while those of type B are abandoned when the specific terms of reference of each is completed.

The accompanying chart shows the membership, terms of reference and the activities performed by the sub-committees in each type.

Relationship between Sub-committees and the Main Committee

The branch secretary is, as always, the backbone of the main committee and he works very closely with the various sub-committees. In fact, many of the sub-committees perform duties which would otherwise be the responsibility of the secretary and thus allow him more time for other work.

The Vice-President, who is the President-Elect, acts as liaison officer reporting to the main committee on the work done, or the recommendations made by each sub-committee. In the past, this has served well to acquaint him of the range of Branch activities which is very useful knowledge to have as a background when he succeeds to the chair.

Sometimes, members of the main committee are appointed convenors of certain sub-committees. This occurs because the individuals have specialised knowledge and their position on the main committee, extending perhaps for several years, brings to the sub-committees all the background data.

The decisions reached by each sub-committee are not necessarily accepted by the main committee. Each recommendation made by a sub-committee is carefully weighed and some may be modified or even rejected, due regard being given to the specialist knowledge and the time taken for the sub-committee to reach its decisions.

Ordinary members of the Branch are kept informed of the activities of each sub-committee through the monthly Newsletter.

J. P. BRIEN, B.Ag.Sc., is a former Secretary of the Victorian Branch.

Organising Sub-committees

In organising a sub-committee, the main committee defines firstly its terms of reference and selects a convenor on the basis of his specialised knowledge or position. It may also suggest possible members.

The convenor then adds his own selected members and, with Committee approval, may even invite non-Institute members, again because of their specialised knowledge or positions.

Once the sub-committee is functioning, convenors make direct contact with each other where there is the likelihood of overlap, or where a coordinated effort on a certain subject is desirable. Convenors also take direct action where circumstances require it, e.g. in releasing a press statement. The main committee requests, however, that it be consulted whenever a matter of policy or expenditure is involved.

It has already been reported that the Refresher School in the plant sciences held in September last year was an outstanding success and this is a reflection of the value of sub-committees to Victorian Branch activities. Two specialist sub-committees (Refresher School and Social) linked to the main committee and acting through an energetic school secretary provided the organisation responsible for this function.

Sub-committee	Membership	Terms of Reference	Activities
TYPE A			
Programme	Private Indus. 1 C.S.I.R.O. 2 — 3	1. To recommend items of branch activity. 2. To devise variations from the formal type of meeting to encourage interest and attendance. 3. To arrange aspects of the Branch programme referred to it.	Arranged speakers for meetings and the annual dinner.
Social	State Dept. 3 — 3	1. To recommend arrangements for conducting social functions. 2. To put into operation arrangements approved by the main committee.	Covered arrangements for annual dinner and welcome to graduands.
Membership	State Dept. 1 University 1 — 2	1. To encourage all eligible persons in Victoria to become members. 2. To devise methods for keeping membership lists up to date.	Two membership drives resulted in 22 additional corporate members.
Publicity and Public Relations	C.S.I.R.O. 2 State Dept. 2 Priv. Indus. 3 — 7	1. To arrange publicity for the Branch. 2. To advise on all statements intended for publication.	Revised the brochure on "Careers in Agricultural Science" and arranged for its reprinting. Also worked on careers film project.
Country Members	State Dept. 6 C.S.I.R.O. 1 — 7	1. To recommend methods and promote ways of giving greater service to members residing in the country.	Surveyed country members for views and recommended a country sub-branch.
Debentures	State Dept. 2 Priv. Indus. 1 — 3	1. To recommend methods to increase the Branch contribution to funds to buy the Wool Bureau Building for the Institute.	Arranged a personal canvass of members which substantially increased the number of debentures from Branch members.
Symposium Report	State Dept. 3 C.S.I.R.O. 2 — 5	1. To prepare a statement for publication from the discussions recorded at the symposium on the "Recruitment and Training of Agricultural Scientists."	Prepared statement for publication.

Sub-committee	Membership	Terms of Reference	Activities
TYPE B			
Membership Qualifications	State Dept. 2 Priv. Indus. 1 3	1. To review the qualifications which should be required for membership with particular reference to Articles 4(ii) and 4(iii) 2. To examine the proposals regarding a Licentiate, Fellowships and the use of "M.A.I.A.S." and similar abbreviations.	Forwarded recommendations on membership qualifications and the letters "M.A.I.A.S."
Agricultural Notebook	State Dept. 1 Uni. 1 Priv. Indus. 1 3	1. To investigate the possibilities and to publish an agricultural notebook similar to the Primrose McConnel's Notebook in Britain.	Made substantial progress on the Notebook project.
Refresher School	State Dept. 3 Priv. Indus. 1 University 2 6	1. To formulate the programme for the 1957 Refresher School.	Devised Refresher School programme.
Deputation	University 1 State Dept. 1 Priv. Indus. 1 3	1. To plan the deputation to the Premier of Victoria to discuss salaries and working conditions.	Prepared the scheme for the deputation in 1957.
TYPE C			
Agricultural Education	C.S.I.R.O. 1 Priv. Indus. 1 State Dept. 1 University 1 4	1. To enquire into various aspects of agricultural education. 2. To deal with other education matters which the main committee may refer to it.	Prepared programme for the symposium on the "Training and Recruitment of Agricultural Scientists".
Undergraduate Affairs	C.S.I.R.O. 1 Priv. Indus. 2 University 1 State Dept. 1 5	1. To review constantly the welfare of undergraduate members of the Institute. 2. To stimulate the interest of these members in the Institute. 3. To investigate ways of increasing the number of student members. 4. To survey first year students to determine the influence of the careers brochure. 5. To promote the scheme to award a Branch prize to a fourth year student.	Interviewed and explained graduate employment to fourth year students. Surveyed effectiveness of the brochure and, in consultation with University, selected Branch prize for top fourth year student.

PERSONAL NOTES

NEW SOUTH WALES

Mr. A. Nelson-Johnson of Agricultural Services Pty. Ltd. recently visited New Guinea to assess the demand for agricultural chemicals there. While in New Guinea Mr. Johnson discussed Institute matters, particularly the formation of a sub-branch, with *Dr. Dorothy Shaw; Mr. R. E. P. Dwyer,* Director of Agriculture in Papua and New Guinea; *Mr. J. Lamrock,* Senior Agricultural Officer, Rabaul; and *Mr. L. Bridgeland,* Officer in Charge, Kerabat Agricultural Experiment Station.

Dr. Lilian R. Fraser, plant pathologist of the N.S.W. Department of Agriculture, returned recently from U.S.A. where she attended an international conference on citrus viruses held at Riverside, California.

Dr. W. V. Single returned to N.S.W. after two years studying for his dgeree as a Farrer Memorial Scholar at the Imperial College of Science and Technology, University of London. Dr. Single has commenced duties at the Agricultural Research Institute, Wagga.

Dr. M. C. Franklin is visiting New Zealand on a C.S.I.R.O. sponsored lecture tour during which he will spend some time at Ruakura.

The Northern Sub-Branch has supplied the following news of three new personalities.

Dr. L. Wheeler is a recent appointment to the Research staff of C.S.I.R.O. at Armidale. Dr. Wheeler was trained at Wye College at Ashford, Kent, and was recently awarded the degree of Doctor of Philosophy from the University of London for a thesis entitled, "The influence of the grazing animal, gang-mowing and nitrogenous fertiliser on the features of the development of a pasture and on the succeeding arable crop."

In his work with the C.S.I.R.O. research team Dr. Wheeler will be concerned with studies of pasture management and utilisation.

Mr. W. S. Vallance, a graduate in Agricultural Science from Massey Agricultural College, University of New Zealand, has recently taken up duties as Research Fellow in Dairy Science at the University of New England, where he proposes to investigate certain fundamental aspects of fat metabolism in the dairy cow. Mr. Vallance has recently submitted to the University of New Zealand a thesis for his Master of Agricultural Science degree dealing with milk secretion and the endocrinology of the udder of dairy cows.

Mr. S. K. Stephenson, a graduate of the University of New Zealand, has recently taken up duties as Lecturer in Genetics in the Faculty of Rural Science at the University of New England.

After taking his B.Sc. at Auckland University College in 1947, Mr. Stephenson spent two years at the Ruakura Animal Research Station and then worked for a year in the Zoology Department at Victoria College, Wellington, and for another year at Massey Agricultural College under Dr. F. W. Dry, the Principal Geneticist.

He was awarded his M.Sc. degree in 1952 for a thesis dealing with fibre type morphology in New Zealand Romney sheep. He also studied a genetic factor in these sheep which causes extreme hairiness in the birth coat.

In 1955 he was awarded a C.S.I.R.O. post-graduate studentship to work for his Doctor of Philosophy degree in the Zoology Department at Sydney University studying wool follicle development and its relation to pre-natal growth and skin expansion in New Zealand Romney sheep.

VICTORIA

Mr. M. A. Cuming, Managing Director of Commonwealth Fertilisers and Chemicals Ltd. has been appointed a Director of Broken Hill Pty. Ltd.

Mr. A. L. Tisdall, formerly Senior Irrigation Officer of the State Rivers and Water Supply Commission, has been appointed a member of the Commission.

QUEENSLAND

Mr. J. F. Miles, who recently won a ballot for a grazing selection in Central Queensland, has resigned from C.S.I.R.O. to take over his property which is situated thirty miles north of Clermont.

John Miles graduated B.Agr.Sc. from the University of Queensland in 1936, and gained the M.Agr.Sc. in 1950. Since 1936 he has been responsible for plant introduction work in Queensland. Between 1936 and 1946 he was stationed at Fitzroyvale near Rockhampton; since then his headquarters have been in Brisbane. During 1951-52 he made a large

collection of plant material on an expedition which covered much of the continent of Africa. In the twenty-one years during which John Miles worked for C.S.I.R.O. the Plant Introduction Section has accumulated what is probably the best existing collection of tropical and sub-tropical pasture plants in the world.

Dr. S. A. Trout, Director of Horticulture, of the Department of Agriculture and Stock, has been made a Fellow of the Royal Australian Chemical Institute for his contribution to the advancement of chemistry in Australia. Dr. Trout's work has been concerned with food preservation and transport problems.

Mr. J. J. Yates has taken up his appointment as a Plant Breeder and Geneticist with Dr. E. M. Hutton in the Plant and Soils Laboratory.

Mr. Ross Tait will become a country member this year when he goes to "Lumeah", Beaudesert, to manage his father's property. Mr. Tait has been on the staff of the University of Queensland for two years as demonstrator in Plant Pathology.

Mr. O. T. Denmead left Brisbane on December 31, 1957, to take up residence at the University of Iowa where he will study agricultural climatology under the direction of Professor R. H. Shaw.

Mr. R. N. Shaw has left Queensland on a visit to South and East Africa.

Dr. D. O. Norris has taken over the duties of President of the Queensland Branch.

SOUTH AUSTRALIA

Dr. N. T. Flentje has been appointed head of the Department of Plant Pathology at the Waite Institute. The appointment carries with it the status of reader in the University.

Dr. K. W. Finlay of the Waite Institute, has been advised of a grant from the Scandinavian and Australian Cultural Funds by the National University to enable him to spend a short time in Sweden and Denmark when he is absent on study leave later this year.

Dr. R. J. Swaby left Adelaide in February for North America and the U.K. He will also visit the U.S.S.R. before returning home.

Professor C. M. Donald, S.A. A.I.A.S. president for 1957, has accepted an invitation from Bovril Ltd. to undertake a survey of their estancias in Argentina. He will leave this month (March). Bovril Ltd. are also financing a fellowship of the University of Adelaide to enable agronomic research to be continued for at least a further two years, and *Stuart Hawkins,* who graduated last year with honors in agronomy, has been appointed to the fellowship. He will leave for Argentina with Prof. Donald.

Dr. J. N. Black has been awarded an Andre Mayer F.A.O. fellowship and left Adelaide in January, to work mainly at the Royal Agricultural College, University of Uppsala. The rest of the time will be spent with the Department of Agriculture at Oxford.

WESTERN AUSTRALIA

Mr. E. Lawson, who has been engaged in post-graduate studies at the Institute of Agriculture, University of W.A., has recently joined the staff of "The Countryman", an agricultural weekly magazine.

Mr. M. M. Wallace, Senior Research Officer in the Entomology Section of C.S.I.R.O. at Crawley, left in January to spend three months in Canberra. While there he will be at the C.S.I.R.O. Entomology Section headquarters.

Mr. R. Moir, Senior Lecturer in Agriculture at the Institute of Agriculture, University of W.A. has left for an overseas trip. He has taken up the position of visiting professor in the Animal Husbandry Section of the College of Agriculture at Logan, Utah. For the first six months he will be carrying out extensive experiments in animal nutrition, especially nitrogen metabolism, working in association with Professor Harris. Later Mr. Moir will visit research centres concerned with animal nutrition, particularly ruminants, in the United States and Britain.

Professor E. J. Underwood, the Director of the Institute of Agriculture at the University of W.A. has recently returned from a six months' tour of America. Working under a grant from the Carnegie Corporation, Professor Underwood has been inquiring into the administration and financing of graduate training and research.

Mr. J. A. Parish, an adviser in the Cereal Laboratory of the Department of Agriculture returned in December from a three months' tour of New South Wales and Victoria where he visited some of the principal centres of cereal research.

Mr. G. Gauntlett, the assistant officer in charge of Irrigation in the Department of Agriculture has been transferred from Harvey to the Head Office in Perth.

Mr. J. A. Carpenter, a post-graduate worker at the Institute of Agriculture, University of W.A. has been awarded the 1958 Australian Services Canteens Trust Fund scholarship which is one of the most valuable awards in Australia. The award entitles the holder to three years' study overseas. Mr. Carpenter will undertake post-graduate research into breeding of grasses at the Grasslands Research Station, London.

Mr. F. Bridgman, an adviser in the Dairying Division of the Department of Agriculture is now at the Wokalup Research Station, where he is in charge of the pasture experiments.

TASMANIA

The ranks of the Tasmanian Branch have recently been swelled by the admission of the following men to the Institute.

Arthur Corbould, B.Sc.Agr., bacteriologist in the Department of Agriculture, Launceston, working on the bacteriology and chemistry of milk.

Edwin J. Clarke, B.Agr.Sc., Assistant Agronomist, Launceston, working on pasture fertilisers.

Frederick K. MacDougall, B.Sc.Ag.(Glas.) District Agricultural Officer, Burnie.

Leon Smith, B.Agr.Sc., Assistant Agronomist (weed control) Hobart.

Adrian Graley, B.Sc., C.S.I.R.O. Soils Division, Hobart.

Recent graduates appointed to the staff of the Tasmanian Department of Agriculture include:—

Patrick Sampson, Assistant Plant Pathologist, Hobart.

Miles Fisher, Assistant D.A.O., King Island.

John Madden, Assistant District Horticultural Officer, Devonport. All three are graduates from the University of Melbourne.

Ian Hicks, a Tasmanian on the N.S.W. Branch books has completed his honours year at Sydney University and has now left for England via tramp steamer. Specific job in England undefined and unknown, but tending towards experience in the commercial world.

Don Martin recently returned from overseas having seen Phillip and Barbara Williams happily installed in the University of Wisconsin. He also saw George Wade at Davis, California. George is now at Cornell, having crossed the U.S.A. in an old Chev. (1952 vintage) via the Southern States.

BRANCH NOTES

NEW SOUTH WALES

The symposium entitled "Drought Mitigation" which was held in October was widely publicised in both city and country press and journals. This joint meeting of the Branch and the Men of the Land Society to discuss an important and topical question proved very successful.

There have been no further general meetings during the November 1957-January 1958 period and the next meeting will be the Annual General Meeting which is being arranged for February 14th.

Meanwhile, the Branch Committee has been called on three occasions, 16th December, 3rd January and 29th January to consider management matters. The Committee has been seriously concerned with the present situation in the south of the State where the problem of membership of Agricultural College diplomates has caused a few members to tender their resignations. The Committee has investigated certain reports and on the basis of details obtained intends making positive recommendations to the incoming Committee.

A survey sub-committee, consisting of Professor J. R. A. McMillan, Mr. C. J. King and Dr. R. L. Reid, has forwarded a questionnaire to all post-war graduates of Sydney University Faculty of Agriculture to assess the employment conditions and opportunities for graduates. A total of 279 questionnaires were distributed and at the end of January some 200 replies had been received. The sub-committee is well pleased with the response obtained and the information received.

In view of the volume of business at present being conducted, the committee is considering the desirability of extending the effective term of office of President to a total of three years. It is proposed that the year preceding his election, a President might be elected Vice-President, convenor of sub-committees and in other ways become acquainted with the details of Institute matters and that following the Presidential year the President might be

elected Immediate Past-President and Principal Delegate.

The Committee is also considering the proposal to arrange a Refresher Course to be held at the Faculty of Agriculture probably in September. The proposal, which was made by the S.U.A.G.A., requires the co-operation of this Branch in organising the series of lectures.

QUEENSLAND

Two meetings were held during November. A social meeting was held on November 6, at which Mr. G. Hughes, Dr. W. A. T. Summerville and Mr. J. Miles showed a collection of interesting slides taken during overseas tours.

On Wednesday, November 27, the Student Prize Meeting was held at the University of Queensland. A total of 23 papers were submitted by third and fourth year Agricultural Science students. The three finalists and their subjects were:—

Mr. G. Diatloff

"Water usage in relation to soil fertility"

Mr. C. Muir

"A comparison of a virgin and an arable black earth from the Darling Downs"

Mr. B. R. Grant

"Some effects of salts of different composition on yield and ion uptake in young barley plants"

After hearing the students present their papers the examining panel chose Mr. B. R. Grant as the winner for 1957.

SOUTH AUSTRALIA

In November, Mr. Marshall Irving, chief of the Animal Industry Division of the SA Department of Agriculture, addressed the SA branch on the "Cattle Industry in Australia". With the N.T. animal industry chief, Col. A. L. Rose, Mr. Irving has been co-author of the plan to free the Adelaide cattle market so that from February cattle have been available without the necessity for pleuropneumonia quarantine.

At the December meeting Dr. N. T. Flentje, head of the Waite Institute's plant pathology department spoke on "Plant Disease Epidemics". Dr. Flentje has recently returned from an extensive overseas study tour.

No meeting of the branch was held in January, over the holiday period.

WESTERN AUSTRALIA

On November 22, 1957, Mr. D. W. R. Stewart, Regional Superintendent, Forests Department, addressed a well attended meeting. His subject, "Forests as a form of land use in the South-west", was of considerable topical interest to all present".

Farmers and Scientists' Joint Conference

Plans are well advanced for this joint conference to be held on February 11 and 12 in Winthrop Hall at the University of W.A. Organised by a Joint Committee of A.I.A.S. and Farmers Union Members, the conference is to consist of eleven papers, four of which are to be presented by farmers.

The Conference was well publicised by both press and radio and at the end of January 530 applications for membership had been received. These have come from farmers, agricultural scientists and representatives of industry (banks, stock firms, etc.). The joint organising committee and the three sub-committees have spared no effort to ensure the success of this function.

TASMANIA

Northern members of the Institute arranged an open meeting in the Conference Room, Department of Agriculture, Launceston on October 10th last.

There was an attendance of approximately 50 made up of members of the Institute, members of the Australian Veterinary Association, members of the Australian Society of Dairy Technology, Department of Agriculture officers and several visitors from the business and farming community.

Professor Sir Samuel Wadham briefly addressed the meeting on problems in extension work and gave his ideas as to how an extension officer can best get the findings of the scientist across to the farmer. He quoted a survey conducted in Victoria by Prof. Oeser, and Drs. Tully and Emery in which farmers were considered as falling into four categories.

A. The experimentalists who were attracted by anything new. They were seldom the best farmers because they were too preoccupied in trying out new ideas on their farms.

B. The sound farmers who were progressive but who were usually cautious about adopting new ideas until they were thoroughly tested and proved. They were usually respected and looked up to in the community and were the real leaders.

C. The average farmers (the majority) who took their lead from those in B.

D. Those who were incapable of making a success of farming.

Prof. Wadham considered that those in category A. provided valuable help to the scientist and the extension officer in testing new ideas and practices and should not be neglected. He suggested however

that extension workers could achieve most by concentrating on those in category B. By influencing this group they were automatically influencing category C and thus were covering the two groups on whom they could expect to exert most effect.

The main speaker of the evening was Dr. A. J. Anderson, Senior Principal Research Officer of the Division of Plant Industry, C.S.I.R.O., Canberra. He gave an illustrated talk on his work on the determination of factors limiting clover growth on problem soils. He spoke particularly of the importance of nutrient interactions in this work and showed how it was common to find that where two factors were limiting, neither gave any response in the absence of the other.

He went on to discuss the relationship between lime, molybdenum, and nodulation in restricting clover growth. Poor nodulation could be due to absence of an effective strain of bacteria, lack of molybdenum or too much acidity for bacteria to survive in the soil or to any combination of these three. In all cases the plant showed nitrogen deficiency symptoms. The solution was to inoculate the seed at sowing with an effective strain of bacteria and to apply molybdenum and lime where necessary. In many cases the high cost of heavy lime applications could be avoided by drilling a small amount of lime with the seed or coating the seed with lime. This enabled the bacteria to survive long enough in the soil to enter the growing seedlings.

Book List

Notice has been received that the following books on agricultural topics have been published recently.

1. Advances in Pest Control Research, V. 1, ed. by R. L. Metcalf, *New York, Interscience Publishers Inc.,* 1957. $11.
2. AUSTRALIA. BUREAU OF AGRICULTURAL ECONOMICS—The Australian Sheep Industry Survey, 1954. Wheat—Sheep Zone, 1957. Free.
3. CASE, H. C. M., and WILLIAMS, D. B.—Fifty Years of Farm Management. *Urbana, University of Illinois Press,* 1957. 61/9.
4. DE ONG, E. R.—Chemistry and Uses of Pesticides, 2nd ed., *New York, Reinhold Publishing Corporation,* 1956. 96/3.
5. DOWSON, W. J.—Plant Diseases Due to Bacteria, 2nd ed., *Cambridge, University Press,* 1957. 32/6 stg.
6. GUTHRIE, J. F.—A World History of Sheep and Wool. Publishers not specified. Printed by *McCarron Bird Pty. Ltd.,* 1957. 45/-.
7. LEVITT, J.—The Hardiness of Plants. *New York, Academic Press Inc.,* 1956. 96/-.
8. MASSEY AGRICULTURAL COLLEGE, Palmerston North. Sheep Farming Annual, 1957. 12/6.
9. SCHWAB, G. O., FREVERT, R. K., BARNES, K. K., TALCOTT, W. E.—Elementary Soil and Water Engineering. *New York, John Wiley & Sons Inc.,* 1957. $6.25.
10. STONE, A. A., and GULVIN, H. E.—Machines for Power Farming. *New York, John Wiley & Sons Inc.,* 1957. $5.95.
11. THOMPSON, H. C., and KELLY, W. C.—Vegetable Crops, 5th ed. *New York, McGraw-Hill,* 1957. Price not known.
12. WOLF, F. A.—Tobacco Diseases and Decays, 2nd ed., rev. and enl. *Durham (North Carolina), Duke University Press,* 1957. 90/-.

Book Review

PLANT PROPAGATION

By John P. Mahlstede and Ernest S. Haber

John Wiley & Sons, Inc., New York 1957

This book is a useful addition to the literature on plant propagation. The first section of the book deals with the fundamentals of plant morphology, physiology and anatomy, as far as these factors are concerned with the processes involved in the multiplication of plant material. This is a useful section for students of the subject who have not already had some training in botany. Then follow details of the sexual propagation of plants. This subject is covered fairly completely from all angles including pollination, seed collection and subsequent seed treatment for flowers, vegetables and trees.

The various methods of vegetative propagation are dealt with from both the fundamental and practical aspects, with a chapter covering the equipment and structures required.

Recent advances in the technology of asexual propagation, including mist propagation, the use of polyethylene film, growth substances and grafting methods are discussed.

The aim of this book is to assist in teaching the fundamentals of propagation and it covers a wide field of ornamentals, vegetables and fruit trees. Consequently there are limits to the details which have been provided for any particular species of plant. However, the final section contains some useful information on the propagation of fruit trees and shrubs of economic importance. For the student requiring more details of any subject there is an excellent list of references at the end of each chapter.

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APPOINTMENT

State Public Service
QUEENSLAND

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APPLICATIONS are invited from qualified persons for appointment as CHIEF PLANT PHYSIOLOGIST, DIVISION OF PLANT INDUSTRY, DEPARTMENT OF AGRICULTURE AND STOCK, BRISBANE, with Salary-Range Minimum £1939/10/- per annum, Maximum £2089/10/- per annum, inclusive of present basic wage adjustments and subject to any further such adjustments.

Salary in excess of the Minimum may be paid according to the qualifications and experience of the appointee.

Applicants should possess a Degree in Science or Agricultural Science of a recognised University, preferably with Honours.

The appointee will be required to undertake and direct research on problems associated with fruit production.

Applications should contain particulars of FULL NAME, ADDRESS, DATE OF BIRTH, marital status, War Service (if any), qualifications and experience and full information as to present employment (if any). Copies of original testimonials in support of the application should be forwarded and there should also be given the names and addresses of two (2) well-known persons as referees in respect to the applicant's character, capabilities and suitability for appointment.

Applications close with the Secretary, Public Service Commissioner's Department, Box 488H, G.P.O., Brisbane, Queensland on 31st March, 1958.

POSITION VACANT

THE UNIVERSITY OF SYDNEY

RESEARCH FELLOWS—McCAUGHEY MEMORIAL INSTITUTE, JERILDERIE, N.S.W.

The McCaughey Memorial Institute is proceeding shortly to appoint two Research Fellows to work on a programme of collaborative research being undertaken in the field of animal production by the University of Sydney and the Commonwealth Scientific and Industrial Research Organization at the University Animal Husbandry Farms, Camden, near Sydney, and at the McCaughey Institute's 24,000 acre property at Jerilderie in south western New South Wales.

The Research Fellows will be attached to the Department of Animal Husbandry of the University of Sydney and will work under the direction of the Professor of Animal Husbandry or of Dr. M. C. Franklin, William McIlwraith Fellow in Animal Husbandry.

Applicants should possess a degree in either Veterinary Science or Agriculture, or in special circumstances in Science, and preferably should have had some post-graduate experience in a field of Animal Husbandry. The Research Fellows will be appointed initially for a period of five years.

Salary will be £1,400-100-£2,050 per annum, plus cost of living adjustment, at present £68 per annum. It is anticipated that one Fellow will reside at Jerilderie, where attractive accommodation and keep will be provided, and the other at Camden or Sydney. Contribution to suitable superannuation or insurance if desired. Further details on application.

Applications, accompanied by a recent photograph and the names of two referees, should be in the hands of the undersigned by 30th April, 1958.

Sydney,
February, 1958

M. A. TELFER,
Registrar.

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